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**Phytotoxicology 2001 and 2002
Investigations: Algoma Ore Division,
Twp. Of Michipicoten (Wawa)**

September 2003

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Ministry of the Environment
Phytotoxicology 2001 and 2002 Investigations:
Algoma Ore Division, Twp. Of Michipicoten (Wawa)

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Report No. Phyto-S5021-2002
September 2003

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PIBS 3918e01

Introduction

For several decades, Algoma Steel Corporation operated an iron ore sintering plant near the Wawa townsite in the Township of Michipicoten. Algoma Ore Division (AOD) mined a low grade iron ore, siderite, at nearby deposits and processed this ore at the sinter plant to reduce the sulphur content and make it more suitable for blast furnace feed. Much of the processed ore was shipped to the Algoma steel making operation in Sault Ste. Marie. The primary air emission from the sinter plant was sulphur dioxide, which caused considerable environmental damage in an area to the north-east, known locally as the “fume-kill zone”.

AOD ceased operations in 1998. The sinter plant has been razed and the mines closed. However, during its operation the sinter plant also released arsenic, which was present in the iron ore, and a concern about the effects of the soil-deposited arsenic on the health of Wawa residents was raised. In response, in 2000 the Wawa Environmental Steering Committee and the Medical Officer of Health for the Algoma Health Unit commissioned a human health risk assessment and an arsenic exposure survey of the Wawa townsite residents. The latter included urine sampling for arsenic determination.

In 2001, in support of the arsenic exposure survey, the MOE Sault Ste. Marie District office requested the assistance of the Phytotoxicology Investigations Unit to sample soil on the residential properties where occupants under the age of 13 had participated in the exposure study. In 2002, additional properties were identified for sampling, either because they were inadvertently excluded the previous year or because other families had joined the exposure study. The properties to be sampled were all identified to the Phytotoxicology investigator as those where urine samples from young residents had been collected. The residential soil arsenic concentrations were provided to the consultant performing the exposure study prior to the preparation of this report.

Additionally, the Phytotoxicology Investigations Unit was asked to evaluate whether the soil concentrations of arsenic encountered on residential properties in Wawa were capable of inhibiting vegetation growth, as arsenic is known to be potentially phytotoxic. In the past, some forms of arsenic were used as herbicide.

Since there were two separate tasks in this investigation, they will be discussed separately in this report.

Investigation Methodology - Residential Property Sampling

Soil samples were collected by Phytotoxicology scientists at 28 residential properties on October 3 and 4, 2001, and at 11 additional properties on July 29, 2002. At most properties two sample sites were established, the sodded portions of the front and rear yards. Occasionally, a side yard was designated as a third sample site. Sampling was conducted using a stainless steel, tube-type soil sampler that extracts a cylindrical core of soil when it is plunged into the ground. Twelve soil cores were collected at each sample site, each to a depth of five centimetres in a grid pattern that covered the entire sample site, and placed into a labelled polyethylene bag. The sampling was repeated to yield duplicate samples from each sample site. The locations of the

properties sampled to support the arsenic exposure survey (i.e. urine analysis) is shown in Figure 1.

Samples were delivered to the Phytotoxicology processing laboratory where they were air dried, sieved through a 2 mm soil sieve to remove stones, roots etc., and then ground in an agate mortar until the soil material passed through a 355 µm soil sieve. Samples were then forwarded to the MOE Laboratory Services Branch for analysis of major and minor soil elements, including arsenic.

Results - Residential Property

All data produced by the analysis of soil samples collected at residential properties are reported in Tables 1, 2 and 3. The data were organized into these three tables based on the locations within the Wawa townsite that samples were collected. Table 1 reports data from properties located along Government Road, near the AOD sinter plant. Table 2 contains data for properties east of Third Avenue and Mission Road. The housing in this area is older and hence it can be assumed that the soil on the property has been less disturbed and exposed to deposition of material from AOD for a longer period of time. Housing west of these streets is newer and hence soil on these properties would have been disturbed by construction and exposed to AOD emissions and arsenic deposition for less time. Data for these properties is reported in Table 3. The soil data in these tables are compared to the Ministry's soil guidelines as outlined in the *Guideline for Use at Contaminated Sites in Ontario* (see Appendix 1). Ministry Table F values are background-based guidelines and Table B are effects-based guidelines. The Ministry's OTR₉₅ guidelines (see Appendix 2) are substituted where there are no Table F values. Table B guidelines are not available for all elements, either because there is insufficient toxicological information to establish a guideline, because the element is naturally present in very high concentrations, or because an element is essential for plant growth. Consistent exceedences of Table F guidelines (in bold font in the tables) are an indication the soil has been impacted by a contaminant source.

Discussion - Residential Property

The primary objective of the 2001 and 2002 investigations was to provide soil arsenic concentration data for use by the consultant in the arsenic exposure study. One part of this study was to determine if there was a relationship between the concentrations of arsenic found in the soil of a residential property, and the urine arsenic concentration of residents, particularly young children residing at that property. The soil data for this objective were provided to the consultant prior to the preparation of this report.

The collection of soil samples at various locations throughout the Wawa townsite, as well as from locations close to the AOD operations, provided an opportunity for a more in-depth analysis of how the long-term sinter plant emissions affected the soil chemistry. The comprehensive analysis of the soil samples produced an extensive database of element

concentrations. This made it possible to look for spacial trends across Wawa as well as relationships between elements, and specifically with arsenic.

The residential sampling locations were separated into three categories based on their proximity to AOD and relative length of time that a property has been used for residential purposes. As shown in Figure 1, only three properties occurring on Government Road near AOD were identified for sampling as part of the exposure study. Seven sites (yards) were sampled from those three properties. All remaining properties were within the Wawa townsite proper. As a result of the low sample number in this part of the townsite spacial concentration trends should be interpreted with caution.

During the sampling it became apparent that the townsite appeared to have been developed in two stages. House uses on the properties east of Third Avenue and Mission Road tended to be older than those to the west of this line. In fact, some to the west were clearly new with some lots still undeveloped.

The rationale for the first category was proximity to AOD; these properties were much closer to the sintering plant than those in the townsite. They were also along a major road that would have been used by vehicles from AOD. These vehicles could have tracked arsenic contaminated material from the plant site. The separation of the second and third category was intuitively based. Properties that contained older housing were more likely to have received air borne deposition of arsenic dust for a longer time period, particularly during the earlier years of AOD's operations when emission controls were less effective. Construction of recent housing would have disturbed the indigenous soil on these properties and could have involved import of topsoil for landscaping. It would, therefore, be reasonable to expect the highest soil arsenic concentrations to the northwest nearest AOD, the next highest in older residential yards on the east side of the townsite, and lower soil arsenic levels in the newer homes west of Third Ave. and Mission Rd. and east of Tamarack Ave.

To determine if a distribution pattern of arsenic was present, frequency distributions of arsenic concentrations for all samples (replicates considered separately) were generated by calculating the frequency of concentrations in the ranges 0-10 µg/g through 90-100 µg/g and >100 µg/g. The results of this analysis are represented in Figure 2. Each graph in Figure 2 also reports the number of samples (N) that were present in each category of properties.

The frequency distribution of arsenic concentrations for the relatively few samples collected from properties near AOD indicates two distinct groups. An examination of Table 1 shows that six samples from one property account for all data in the 0-10 µg/g range, while the remaining eight samples from two other properties in the same vicinity account for all data in the high concentrations ranges, i.e. greater than 60 µg/g.

A possible explanation is house age. The two properties with the high arsenic concentrations contain houses that appear to be several decades in age. Consequently, their yards have, in all probability not been disturbed since the houses were constructed. The soil in these yards would have received and retained arsenic and other elements that were emitted by AOD. They are also situated next to a road that would have been used by vehicles leaving the AOD site, possibly tracking arsenic contamination from the site itself.

The third property contained a house of recent construction, surrounded by yards that were meticulously landscaped and maintained. It is highly probable that the soil at the surface (which was sampled) is not indigenous to this property, and has not received the deposition of arsenic that other nearby soil has. Also, the residential portion of this property is set in a cleared part of a wooded area, well back from the public road. Evidence that the arsenic data reported for this residential yard is not indicative of the deposition that fell onto the woodlot around the property is provided in the data for the bioassay soil collected from Site 9, which happened to be just a few metres from the rear lawn. The arsenic concentration for this soil was 143 $\mu\text{g/g}$ (Table 5), whereas the soil from the adjacent residential lawn had less than 7 $\mu\text{g/g}$ arsenic (Table 1).

The frequency distributions for all remaining properties, separated into those on the older east part of Wawa and those on the newer west part of the townsite, distinguish themselves from the two properties near AOD (which are probably more typical of others near AOD) because they had arsenic concentrations that are almost all below 40 $\mu\text{g/g}$. In comparison, all soil samples from the two properties near AOD were above 60 $\mu\text{g/g}$ arsenic.

Having established that residential property soil in the townsite proper has much lower arsenic concentrations on average than at those properties near AOD, it is worthwhile to see if there are any distinctions between east and west Wawa. The similarities between these two groups lies in the near identical frequencies in the 10-20 $\mu\text{g/g}$ and 20-30 $\mu\text{g/g}$ intervals. The differences are in the higher frequency of samples with more than 30 $\mu\text{g/g}$ arsenic from the eastern older side of the townsite and a concomitant higher frequency of samples with less than 10 $\mu\text{g/g}$ from the western side.

If this trend is in fact real, then two explanations can be proposed. First of all, older properties would have been subjected to longer periods of arsenic deposition. Secondly, many of the west side properties are very new housing sites and the possibility of uncontaminated landscaping soil being used to finish the yards appears highly probable. Never-the-less, most of the Wawa townsite properties have reasonably low arsenic concentrations compared to those near AOD. These townsite properties were probably not subjected to fugitive or vehicle-tracked dust from AOD. Also, because of the relatively low height of the AOD stack, the ridge between AOD and the townsite, and the predominantly southwest winds during the non-snow season, much of the stack emissions would have bypassed the townsite depositing instead in the "fume-kill zone" to the northeast. The soil arsenic levels are highest on the residential properties along Government Rd. nearest AOD because these properties are among the oldest in town and are very close to AOD and so they would have been impacted not only by stack deposition but also from fugitive emissions off the AOD plant site and from vehicle traffic.

The final point of discussion regarding the arsenic data has to focus on what appears to be an anomalous property in the east Wawa group. One sample from the back yard was determined to contain 300 $\mu\text{g/g}$ of arsenic (see Table 2). This datum was substantiated by repeat laboratory analysis. The duplicate sample for that yard contained 37 $\mu\text{g/g}$. It is clear that a very heterogeneous distribution of arsenic is present in the back yard soil at this property. The source of arsenic at this property was not identified but given that at least one other property had fill material imported from the AOD site, it is possible that others may have also. The most

probable use of such material would have been for driveway surfaces, construction aggregate, and fill.

As is evident in the data tables, the soil samples were analysed for much more than just arsenic. Given that these data are available, a brief look at the other soil elements is warranted. A statistical procedure was performed that provided correlation coefficients between each possible pair of elements. The results of this analysis is reported in Table 4 as a correlation matrix.

Due to the high number of samples available for this analysis, the level at which the correlation can be considered statistically significant is very low. In this analysis there were 162 samples and any correlation coefficient (r) with an absolute value of about 0.150 indicates a significant correlation at a confidence level of 99% ($p < 0.01$). A positive r value means as one element increases the other element also increases in a consistent proportion. A negative r value indicates one element goes down in concentration as the other increases, or visa versa. The higher the r value the more consistent the relationship between the two and the greater the likelihood of a common origin. Clearly, there are many significant correlations between the concentrations of various pairs of elements in the soil samples collected.

It would be more useful, however, to focus only on those correlations that have the highest r values, and more specifically, those that are co-related to arsenic. To that end, the elements that are most highly correlated with arsenic are iron ($r=0.6355$) and manganese ($r=0.6577$). The correlation between iron and manganese is even greater ($r=0.9270$). This implies that iron and manganese concentrations are likely to be elevated on properties that have high arsenic levels. Since iron is naturally high in soil and both iron and manganese are essential plant nutrients, slightly elevated concentrations of these two elements should not adversely affect plant growth. Given that the purpose of the AOD operation was to process iron ore, and the ore was an arseno-pyrite, the arsenic-iron correlation could be expected. The fact that manganese emissions also occurred can be readily reconciled since the ore processed at AOD contained significant quantities of manganese.

Investigation Methodology - Bioassay

Arsenic can be phytotoxic, and concentrations above the MOE generic effects-based Table A guideline of 20 $\mu\text{g/g}$ may cause injury to sensitive plant species. As this and previous Phytotoxicology investigations around Wawa have documented, soil arsenic concentrations in this community can substantially exceed the MOE generic Table A soil guideline. However, with the exception of the fume-kill zone, vegetation impacts have not been observed in the Wawa area. Although soil arsenic levels can be quite elevated in the fume-kill zone it is not likely that arsenic is a significant contributor to the vegetation damage in that area. The main reason the vegetation has been so dramatically impacted in the fume-kill zone is because of years of intense fumigation by sulphur dioxide, which killed the plants outright. With the plants destroyed and the organic matter in the soil eroded the site is very harsh and exposed and subject to extremes of heat, cold, and moisture stress, making it very difficult for forest-type plants to re-

colonize the fume-kill zone. With the complete cessation of emissions from AOD large areas of the fume-kill zone have re-vegetated with grasses and shrubs, particularly blueberry.

During the residential property sampling, bulk soil was collected at ten locations which were likely to provide a wide range of soil arsenic concentrations. This soil was collected for a bioassay to be conducted at the Phytotoxicology controlled environment laboratory to determine whether the concentrations of arsenic in the soil in Wawa are capable of causing an adverse effect on vegetation.

Once a candidate location was identified, a portable X-ray fluorescence spectrophotometer was used as a field screening measurement to determine the approximate soil arsenic concentration at that location to ensure that soil with a wide arsenic concentration range was being obtained. A garden spade was used to collect approximately ten litres of soil from the uppermost five centimetres at each site. Most of the locations could be described as parks, undeveloped green spaces, or vacant land near the sinter plant property. One location was a pile of soil and rock mixture that was to be used as fill on a residential property and was reported to have originated from the sinter plant property. The locations from which the bioassay soil was obtained are shown in Figure 1. The soil arsenic concentrations in the 10 bioassay samples ranged from 14 µg/g to 533 µg/g (see Table 5).

After air drying, the soil was screened through a two millimetre sieve and the sieved fraction was set aside for the bioassay. Samples for chemical analysis were taken from the now thoroughly homogenized bulk soil for laboratory quality assurance purposes, to confirm the field-screened arsenic levels, and insure there were no potentially phytotoxic levels of other chemical elements. Four replicate samples were taken from the three bulk samples collected in 2001 and three from the seven bulk samples collected in 2002. Processing of these samples destined for chemical analysis followed the same procedures as for the residential samples. In addition to soil with low arsenic concentrations (two sites with 14 µg/g and one site with 15 µg/g) collected from the Wawa area, a greenhouse potting soil was also used as a control. The control potting soil contained less than 17 µg/g arsenic.

Bioassay Methodology

Each of the 10 bioassay soils, now thoroughly homogenized and screened to less than 2 mm, were transferred into three plastic pots. On August 14, 2002, each pot was seeded with five bush bean seeds (a standard bioassay plant known to be very sensitive to arsenic), watered, and placed into a temperature, lighting, and humidity controlled growth chamber. The seeds were allowed to germinate and the plants to develop. The young plants were watered as required. No fertilizer was added. The bioassay ended on September 19, 2004, after 35 days. The pots were removed from the chamber and the plants were photographed. Measurements of above ground plant biomass fresh weight, shoot length, and root elongation were recorded.

Bioassay Results

The chemistry of the bioassay soil samples is reported in Table 5. Values are reported as means of the four replicate samples. Arsenic was the only element that exceeded MOE Table A generic effects-based soil guidelines. Some bioassay treatment soils had levels of iron, magnesium, manganese, and/or zinc that were marginally higher than normal background concentrations, but all were well below the Ministry's Table A generic effects-based soil guidelines. These marginally elevated concentrations of iron, manganese, magnesium, and zinc would not have adversely affected plant growth, in fact they may have been beneficial as they are all nutrient elements that are essential for plant growth.

Photographs were taken at the end of the bioassay and are represented in Figure 3. These images have been cropped and scaled so that each image is at the same scale and a visual comparison of the response of the bean grown in the ten different soils can be readily made.

Table 6 summarizes the bean growth measurements for each soil arsenic treatment. The mean above ground plant biomass fresh weight was greatest for bean plants grown in 110 µg/g arsenic, whereas the mean shoot length was longest at 14 µg/g soil arsenic, and on average the plants with the longest roots grew in 350 µg/g soil arsenic. On average, plant above ground biomass, shoot length, and root length were all marginally greater at the highest soil arsenic concentration of 533 µg/g than the greenhouse control soil which contained less than 17 µg/g.

Discussion - Bioassay

The images in Figure 3 clearly illustrate the relatively uniform growth obtained in all bioassay soil treatments. The similar between-treatment growth illustrated in Figure 3 is supported by the plant measurements summarized in Table 6, which indicated that there was no consistent relationship between plant growth and soil arsenic concentration, and that plant growth was similar across the range of soil arsenic treatments.

Most seeds germinated and bean plants developed with no signs of toxicity. Arsenic toxicity typically induces black, necrotic leaf tissue and blackened, knotted, and shortened roots. There was no difference in bean germination or apparent difference in plant growth between soil arsenic levels. In some pots a fungal infection slightly inhibited growth on a few plants. Slight differences in total plant height were not related to soil arsenic concentration and were likely the result of varying fertility levels in the test soil (no fertilizer was added).

No injury symptoms characteristic of arsenic toxicity were observed on any of the bioassay plants at any soil arsenic concentration. The highest soil arsenic concentration tested was 533 µg/g, or about 26 times the MOE Table A generic effects-based arsenic soil guideline. The absence of arsenic toxicity symptoms in the soil bioassay is consistent with the complete lack of arsenic symptomatology on vegetation in Wawa - no injury symptoms characteristic of arsenic toxicity on vegetation have been observed by Phytotoxicology investigators since intensive Ministry studies were initiated in 1998.

In order for injury to occur the arsenic must be biologically available to the plant, which means it must be soluble in water and taken up through the roots. The arsenic in soil in Wawa must be very insoluble in water because no injury was observed in the bioassay plants, or plants anywhere in the Wawa townsite, and no adverse impacts were measured in bioassay plants at the maximum soil arsenic concentration tested (533 µg/g). Therefore, the risk to the terrestrial ecosystem in Wawa from elevated soil arsenic concentrations is concluded to be very low. The bioassay results are completely consistent with observations of vegetation health in the general Wawa area and support the conclusions that elevated soil arsenic concentrations, up to the maximum tested concentration of 533 µg/g, will not adversely affect plant growth and therefore there are no restrictions to the normal use of residential properties in Wawa.

Conclusions

The primary objective of this investigation was to provide data on arsenic concentrations in soil of specific residential properties to support health studies. This objective was met by providing these data to the appropriate parties before this summary report was prepared.

The sampling of numerous properties at the Wawa townsite as well as in the vicinity of AOD provided a sizeable database of soil element concentrations that permitted a general evaluation of soil contamination. This evaluation demonstrated that arsenic concentrations in residential property soil for the Wawa townsite were generally less than 50 µg/g, with a few exceptions on properties closest to AOD or where contaminated soil or aggregate material was brought to the property.

Properties near the AOD site consistently had higher arsenic levels. These properties would have been subject to more intense deposition of AOD atmospheric and fugitive emissions, as well as tracking of the contaminant by vehicles from AOD.

The bioassay revealed that symptoms of arsenic toxicity could not be induced in a sensitive plant species at soil arsenic concentrations up to 533 µg/g, which is considerably higher than all but a few of the most contaminated residential Wawa residential properties nearest AOD. In conclusion, the form of arsenic in the soil in Wawa must be very insoluble and therefore biologically unavailable, and so the risk to the terrestrial ecosystem in the Wawa area from elevated soil arsenic concentrations is concluded to be very low. The bioassay results are completely consistent with observations of vegetation health in the general Wawa area and support the conclusions that elevated soil arsenic concentrations, up to the maximum tested concentration of 533 µg/g, will not adversely affect plant growth and therefore there are no restrictions to the normal use of residential properties in Wawa.

Table 1: Soil Element Concentrations (µg/g) on Residential Yards of Properties Near Algoma Ore Division

| Address | Yard | Ca | Fe | Al | Mg | Mn | Ba | Zn | V | Sr | Cr | Pb | Cu | Ni | Co | As | Be | Mo | Cd |
|--------------------------|-------|-------|-------|-------|-------|------|-----|-----|-----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| A Government Rd. | front | 3300 | 14000 | 12000 | 2900 | 320 | 59 | 46 | 25 | 16 | 31 | 33 | 35 | 31 | 5.5 | 3.9 | 0.5 | <W | 0.2 |
| A Government Rd. | front | 3800 | 14000 | 10000 | 3100 | 360 | 47 | 39 | 26 | 18 | 29 | 22 | 27 | 24 | 6.2 | 4.5 | 0.5 | <W | 0.3 |
| A Government Rd. | side | 3200 | 10000 | 5400 | 2600 | 240 | 15 | 16 | 19 | 13 | 19 | 9.0 | <T | 7.0 | 11 | 4.4 | 4.0 | 0.5 | <W |
| A Government Rd. | side | 3600 | 12000 | 6300 | 2900 | 320 | 18 | 21 | 21 | 15 | 22 | 10 | 9.0 | 13 | 4.8 | 5.1 | 0.5 | <W | 0.2 |
| A Government Rd. | back | 3800 | 11000 | 5900 | 3100 | 270 | 16 | 17 | 18 | 13 | 21 | 13 | 7.0 | 12 | 4.6 | 3.9 | 0.5 | <W | 0.2 |
| A Government Rd. | back | 5000 | 11000 | 5400 | 3400 | 280 | 15 | 17 | 18 | 13 | 21 | 9.0 | <T | 8 | 11 | 4.3 | 6.4 | 0.5 | <W |
| B Government Rd. | front | 4700 | 42000 | 12000 | 4900 | 1900 | 63 | 99 | 35 | 22 | 36 | 43 | 43 | 33 | 7.6 | 98 | 0.5 | <W | 1.1 |
| B Government Rd. | front | 4800 | 33000 | 18000 | 4500 | 1200 | 88 | 93 | 38 | 25 | 44 | 24 | 63 | 47 | 8.0 | 69 | 0.7 | <T | 0.4 |
| B Government Rd. | back | 5300 | 47000 | 8900 | 5200 | 2100 | 55 | 120 | 31 | 21 | 28 | 49 | 27 | 20 | 6.2 | 100 | 0.5 | <W | 0.7 |
| B Government Rd. | back | 5500 | 51000 | 9500 | 6300 | 2300 | 46 | 130 | 31 | 18 | 32 | 35 | 37 | 25 | 8.7 | 110 | 0.5 | <W | 1.1 |
| C Government Lane | front | 4800 | 44000 | 8800 | 5700 | 1900 | 32 | 130 | 29 | 20 | 33 | 57 | 27 | 25 | 8.3 | 89 | 0.5 | <W | 0.9 |
| C Government Lane | front | 5100 | 44000 | 9300 | 5700 | 2000 | 35 | 130 | 29 | 21 | 35 | 63 | 28 | 24 | 8.3 | 96 | 0.5 | <W | 1.1 |
| C Government Lane | back | 3800 | 25000 | 7100 | 3600 | 1100 | 31 | 63 | 21 | 13 | 22 | 24 | 16 | 21 | 5.5 | 72 | 0.5 | <W | 0.3 |
| C Government Lane | back | 4200 | 26000 | 6700 | 3800 | 1100 | 28 | 120 | 21 | 15 | 24 | 23 | 13 | 16 | 5.4 | 84 | 0.5 | <W | 0.2 |
| MOE Background Guideline | | 58000 | 33000 | 27000 | 16000 | 1300 | 210 | 160 | 91 | 78 | 71 | 120 | 85 | 43 | 21 | 17 | 1.2 | 2.5 | 1.0 |
| MOE Effects Guideline | | NG | NG | NG | NG | NG | 750 | 600 | 200 | NG | 750 | 200 | 225 | 200 | 40 | 20 | 1.2 | 40 | 12 |

Background guidelines are Table F and Effects guidelines are Table A in the MOE Guideline for Use at Contaminated Sites (1997), OTR98 used where no Table F is available, see Appendix.

NG - no Table A Effects guideline available.

Table 2: Soil Element Concentrations (µg/g) on Residential Yards, Wawa Townsite Properties East of Third Ave. & Mission Rd.

| Address | Yard | Ca | Fe | Al | Mg | Mn | Ba | Zn | V | Sr | Cr | Pb | Cu | Ni | Co | As | Be | Mo | Cd |
|--------------------------|-------|-------|-------|-------|-------|------|-----|-----|-----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| D Wood Ave. | front | 3700 | 20000 | 12000 | 4100 | 580 | 42 | 65 | 37 | 21 | 35 | 23 | 24 | 21 | 7.7 | 22 | 0.5 | 0.5 | <T |
| D Wood Ave. | front | 3400 | 19000 | 11000 | 3800 | 540 | 40 | 52 | 35 | 19 | 34 | 22 | 22 | 20 | 7.1 | 16 | 0.5 | 0.5 | <T |
| D Wood Ave. | back | 2800 | 19000 | 14000 | 3500 | 510 | 34 | 62 | 36 | 18 | 31 | 17 | 20 | 21 | 7.2 | 15 | 0.5 | 0.5 | <T |
| D Wood Ave. | back | 2500 | 16000 | 12000 | 3200 | 380 | 26 | 47 | 31 | 17 | 28 | 11 | 13 | 17 | 5.9 | 9.6 | 0.5 | 0.5 | <T |
| E Second Ave. | front | 4300 | 18000 | 12000 | 3200 | 540 | 69 | 68 | 32 | 22 | 29 | 41 | 25 | 18 | 5.9 | 23 | 0.5 | 0.7 | <T |
| E Second Ave. | front | 5200 | 19000 | 11000 | 3300 | 580 | 83 | 67 | 33 | 26 | 28 | 37 | 29 | 18 | 6.3 | 18 | 0.5 | 1.1 | <T |
| E Second Ave. | back | 5300 | 26000 | 14000 | 5200 | 820 | 67 | 110 | 43 | 23 | 44 | 27 | 26 | 29 | 11 | 25 | 0.5 | 0.6 | <T |
| E Second Ave. | back | 4000 | 22000 | 12000 | 4100 | 740 | 52 | 93 | 34 | 20 | 35 | 32 | 20 | 23 | 7.4 | 25 | 0.5 | 0.5 | <T |
| F Second Ave. | front | 5900 | 24000 | 11000 | 4000 | 720 | 46 | 120 | 33 | 26 | 33 | 42 | 31 | 27 | 7.5 | 21 | 0.5 | 0.5 | <T |
| F Second Ave. | front | 4900 | 23000 | 11000 | 3700 | 670 | 44 | 100 | 34 | 21 | 33 | 42 | 25 | 18 | 6.8 | 21 | 0.5 | 0.6 | <T |
| F Second Ave. | back | 4700 | 30000 | 12000 | 5000 | 980 | 50 | 170 | 39 | 22 | 35 | 120 | 34 | 25 | 9.2 | 35 | 0.5 | 0.5 | <T |
| F Second Ave. | back | 5200 | 30000 | 11000 | 4700 | 970 | 54 | 190 | 37 | 22 | 38 | 140 | 37 | 25 | 8.8 | 38 | 0.5 | 0.5 | <T |
| G Main St. | front | 4800 | 17000 | 8200 | 3300 | 590 | 73 | 81 | 28 | 23 | 23 | 40 | 23 | 18 | 5.7 | 18 | 0.5 | 0.5 | <T |
| G Main St. | front | 4800 | 17000 | 8500 | 3500 | 520 | 82 | 77 | 30 | 26 | 26 | 42 | 24 | 19 | 5.8 | 18 | 0.5 | 0.5 | <T |
| G Main St. | back | 3100 | 14000 | 8500 | 2700 | 370 | 39 | 72 | 27 | 19 | 23 | 34 | 12 | 14 | 4.9 | 14 | 0.5 | 0.5 | <T |
| G Main St. | back | 3000 | 13000 | 8200 | 2600 | 340 | 37 | 70 | 26 | 19 | 21 | 25 | 12 | 13 | 4.9 | 10 | 0.5 | 0.5 | <T |
| H Joliet St. | front | 5800 | 16000 | 9800 | 3900 | 420 | 35 | 46 | 31 | 24 | 31 | 24 | 24 | 19 | 7.4 | 7.5 | 0.5 | 0.5 | <T |
| H Joliet St. | front | 5200 | 15000 | 9200 | 3700 | 360 | 31 | 39 | 32 | 22 | 29 | 18 | 22 | 18 | 6.5 | 11 | 0.5 | 0.5 | <T |
| H Joliet St. | back | 3500 | 14000 | 9500 | 3400 | 380 | 40 | 63 | 28 | 19 | 31 | 19 | 19 | 19 | 6.7 | 15 | 0.5 | 0.5 | <T |
| H Joliet St. | back | 3200 | 14000 | 9000 | 3400 | 380 | 35 | 56 | 28 | 19 | 34 | 19 | 17 | 17 | 6.3 | 15 | 0.5 | 0.5 | <T |
| I Centennial Ave. | front | 5700 | 25000 | 16000 | 5000 | 800 | 49 | 66 | 53 | 22 | 44 | 22 | 33 | 25 | 11 | 19 | 0.5 | 0.8 | <T |
| I Centennial Ave. | front | 5800 | 26000 | 17000 | 5600 | 840 | 49 | 73 | 53 | 22 | 48 | 26 | 39 | 27 | 12 | 15 | 0.5 | 1.5 | <T |
| I Centennial Ave. | back | 3700 | 15000 | 10000 | 2500 | 420 | 38 | 57 | 30 | 16 | 23 | 24 | 15 | 12 | 4.9 | 15 | 0.5 | 0.5 | <T |
| I Centennial Ave. | back | 3900 | 16000 | 10000 | 2400 | 450 | 42 | 63 | 32 | 18 | 21 | 19 | 13 | 13 | 4.6 | 18 | 0.5 | 0.5 | <T |
| J Broadway Ave. | front | 4300 | 16000 | 11000 | 3200 | 480 | 54 | 52 | 30 | 23 | 29 | 27 | 38 | 17 | 5.7 | 17 | 0.5 | 0.5 | <T |
| J Broadway Ave. | front | 4300 | 16000 | 10000 | 3100 | 480 | 51 | 60 | 29 | 19 | 33 | 25 | 20 | 16 | 5.8 | 15 | 0.5 | 0.5 | <T |
| J Broadway Ave. | back | 3100 | 15000 | 11000 | 2700 | 460 | 46 | 79 | 27 | 16 | 27 | 22 | 20 | 19 | 5.6 | 16 | 0.5 | 0.5 | <T |
| J Broadway Ave. | back | 3100 | 14000 | 11000 | 2800 | 400 | 45 | 74 | 26 | 18 | 25 | 22 | 16 | 17 | 5.5 | 17 | 0.5 | 0.5 | <T |
| MOE Background Guideline | | 58000 | 33000 | 27000 | 16000 | 1300 | 210 | 160 | 91 | 78 | 71 | 120 | 85 | 43 | 21 | 17 | 1.2 | 2.5 | 1.0 |
| MOE Effects Guideline | | NG | NG | NG | NG | NG | 750 | 600 | 200 | NG | 750 | 200 | 225 | 200 | 40 | 20 | 1.2 | 40 | 12 |

Background guidelines are Table F and Effects guidelines are Table A in the MOE Guideline for Use at Contaminated Sites (1997), OTR98

used where no Table F is available, see Appendix.

NG - no Table A Effects guideline available.

Table 2: Soil Element Concentrations (µg/g) on Residential Yards, Wawa Townsite Properties East of Third Ave. & Mission Rd.

| Address | Yard | Ca | Fe | Al | Mg | Mn | Ba | Zn | V | Sr | Cr | Pb | Cu | Ni | Co | As | Be | Mo | Cd |
|--------------------------|-------|-------|-------|-------|-------|------|-----|-----|-----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| K Toronto Ave. | front | 8100 | 22000 | 12000 | 4100 | 790 | 80 | 200 | 33 | 28 | 37 | 82 | 28 | 21 | 7.3 | 20 | 0.5 | <W | 1.1 |
| K Toronto Ave. | front | 7200 | 22000 | 13000 | 4200 | 790 | 79 | 160 | 37 | 27 | 44 | 63 | 29 | 23 | 8.2 | 19 | 0.5 | <W | 0.8 |
| K Toronto Ave. | back | 3900 | 15000 | 12000 | 3500 | 450 | 43 | 93 | 31 | 19 | 31 | 28 | 24 | 19 | 6.3 | 17 | 0.5 | <W | 0.4 |
| K Toronto Ave. | back | 3800 | 16000 | 12000 | 3600 | 480 | 44 | 98 | 34 | 20 | 31 | 29 | 23 | 19 | 7.3 | 16 | 0.5 | <W | 0.6 |
| L Toronto Ave. | front | 3400 | 12000 | 7800 | 3000 | 270 | 28 | 46 | 25 | 20 | 24 | 20 | 13 | 14 | 4.9 | 9.6 | 0.5 | <W | 0.4 |
| L Toronto Ave. | front | 3400 | 15000 | 8400 | 3100 | 380 | 34 | 71 | 29 | 21 | 26 | 26 | 16 | 15 | 5.4 | 8.6 | 0.5 | <W | 0.2 |
| L Toronto Ave. | back | 3500 | 12000 | 7900 | 2700 | 250 | 33 | 66 | 23 | 19 | 22 | 21 | 10 | 13 | 4.9 | 5.8 | 0.5 | <W | 0.3 |
| L Toronto Ave. | back | 3600 | 12000 | 7500 | 2600 | 290 | 39 | 82 | 21 | 18 | 21 | 38 | 11 | 13 | 4.9 | 9.8 | 0.5 | <W | 0.5 |
| M Toronto Ave. | front | 3600 | 17000 | 11000 | 3200 | 450 | 40 | 73 | 33 | 18 | 33 | 41 | 23 | 17 | 6.3 | 20 | 0.5 | <W | 0.5 |
| M Toronto Ave. | front | 3600 | 17000 | 10000 | 3700 | 440 | 37 | 68 | 32 | 19 | 33 | 42 | 27 | 19 | 7.9 | 14 | 0.5 | <W | 0.7 |
| M Toronto Ave. | back | 3600 | 16000 | 9800 | 3200 | 470 | 39 | 76 | 29 | 19 | 27 | 30 | 14 | 16 | 5.4 | 19 | 0.5 | <W | 0.6 |
| M Toronto Ave. | back | 3200 | 15000 | 9000 | 3000 | 420 | 35 | 66 | 28 | 18 | 25 | 22 | 13 | 15 | 5.6 | 17 | 0.5 | <W | 0.4 |
| N Toronto Ave. | front | 5500 | 21000 | 15000 | 4700 | 860 | 58 | 130 | 37 | 22 | 43 | 16 | 35 | 34 | 10 | 20 | 0.5 | <W | 0.3 |
| N Toronto Ave. | front | 5100 | 20000 | 14000 | 4200 | 890 | 54 | 120 | 34 | 22 | 42 | 15 | 32 | 30 | 8.8 | 21 | 0.5 | <W | 0.4 |
| N Toronto Ave. | back | 3600 | 18000 | 9900 | 3800 | 530 | 34 | 70 | 33 | 21 | 30 | 21 | 17 | 18 | 6.5 | 20 | 0.5 | <W | 0.3 |
| N Toronto Ave. | back | 4100 | 16000 | 9700 | 3600 | 630 | 46 | 88 | 32 | 21 | 31 | 15 | 14 | 17 | 6.6 | 16 | 0.5 | <W | 0.6 |
| O First Ave. | front | 5000 | 25000 | 14000 | 4000 | 870 | 68 | 150 | 41 | 27 | 42 | 40 | 45 | 26 | 9.3 | 41 | 0.5 | <W | 0.8 |
| O First Ave. | front | 7100 | 23000 | 11000 | 4900 | 860 | 49 | 110 | 38 | 25 | 39 | 43 | 27 | 21 | 7.9 | 41 | 0.5 | <W | 0.6 |
| O First Ave. | back | 7100 | 33000 | 13000 | 5900 | 1300 | 53 | 130 | 43 | 28 | 48 | 48 | 35 | 28 | 9.8 | 300 | 0.5 | <W | 0.4 |
| O First Ave. | back | 4600 | 22000 | 12000 | 3400 | 730 | 60 | 160 | 35 | 24 | 36 | 190 | 41 | 21 | 7.9 | 37 | 0.5 | <W | 1.2 |
| P First Ave. | front | 4600 | 22000 | 13000 | 4400 | 750 | 42 | 82 | 36 | 22 | 45 | 38 | 31 | 22 | 9.2 | 22 | 0.5 | <W | 1.4 |
| P First Ave. | front | 4600 | 22000 | 13000 | 4400 | 770 | 41 | 82 | 37 | 21 | 43 | 41 | 32 | 22 | 9.0 | 18 | 0.5 | <W | 1.3 |
| P First Ave. | back | 3700 | 20000 | 11000 | 3200 | 620 | 38 | 46 | 34 | 17 | 28 | 23 | 15 | 15 | 5.3 | 22 | 0.5 | <W | 0.9 |
| P First Ave. | back | 4100 | 18000 | 11000 | 2800 | 620 | 40 | 48 | 32 | 17 | 25 | 44 | 15 | 14 | 5.1 | 24 | 0.5 | <W | 1.0 |
| Q Nyman Ave. | front | 3100 | 11000 | 7500 | 2300 | 290 | 23 | 37 | 22 | 15 | 26 | 14 | 10 | 12 | 4.6 | 9.4 | 0.5 | <W | 0.8 |
| Q Nyman Ave. | front | 2800 | 10000 | 7400 | 2200 | 270 | 22 | 31 | 21 | 15 | 25 | 12 | 8.0 | 11 | 4.1 | 8.2 | 0.5 | <W | 0.6 |
| Q Nyman Ave. | back | 2500 | 12000 | 7200 | 2600 | 330 | 26 | 33 | 23 | 12 | 21 | 8.0 | 12 | 13 | 5.7 | 12 | 0.5 | <W | 0.5 |
| Q Nyman Ave. | back | 2900 | 12000 | 7300 | 2700 | 320 | 27 | 33 | 23 | 14 | 20 | 9.0 | 11 | 12 | 5.0 | 11 | 0.5 | <W | 0.6 |
| MOE Background Guideline | | 58000 | 33000 | 27000 | 16000 | 1300 | 210 | 160 | 91 | 78 | 71 | 120 | 85 | 43 | 21 | 17 | 1.2 | 2.5 | 1.0 |
| MOE Effects Guideline | | NG | NG | NG | NG | NG | 750 | 600 | 200 | NG | 750 | 200 | 225 | 200 | 40 | 20 | 1.2 | 40 | 12 |

Background guidelines are Table F and Effects guidelines are Table A in the MOE Guideline for Use at Contaminated Sites (1997), OTR98

used where no Table F is available, see Appendix.

NG - no Table A Effects guideline available.

on Rd.

| Address | Yard | Ca | Fe | Al | Mg | Mn | Ba | Zn | V | Sr | Cr | Pb | Cu | Ni | Co | As | Be | Mo | Cd |
|--------------------------|-------|-------|-------|-------|-------|------|-----|-------|-----|----|-----|--------|-----|-----|-----|-----|--------|--------|--------|
| R Beck Ave. | front | 3900 | 19000 | 10000 | 4900 | 510 | 29 | 54 | 35 | 23 | 35 | 25 | 20 | 24 | 8.0 | 7.4 | 0.5 <W | 0.5 <W | 0.2 <W |
| R Beck Ave. | front | 4300 | 20000 | 10000 | 5200 | 580 | 33 | 64 | 36 | 24 | 37 | 20 | 24 | 25 | 8.8 | 12 | 0.5 <W | 0.5 <W | 0.5 <T |
| R Beck Ave. | back | 3200 | 21000 | 11000 | 3000 | 640 | 42 | 82 | 32 | 20 | 25 | 28 | 11 | 16 | 5.2 | 23 | 0.5 <W | 0.8 <T | 0.6 <T |
| R Beck Ave. | back | 2900 | 21000 | 12000 | 2800 | 610 | 38 | 60 | 34 | 19 | 24 | 23 | 11 | 15 | 4.9 | 24 | 0.5 <W | 0.5 <W | 0.6 <T |
| S Maple St. | front | 4200 | 16000 | 11000 | 3400 | 400 | 33 | 34 | 32 | 21 | 27 | 15 | 22 | 29 | 6.4 | 17 | 0.5 <W | 0.6 <T | 0.5 <T |
| S Maple St. | front | 3200 | 15000 | 10000 | 2800 | 360 | 28 | 28 | 28 | 18 | 26 | 8.0 <T | 17 | 23 | 5.4 | 17 | 0.5 <W | 0.5 <W | 0.2 <W |
| S Maple St. | side | 4000 | 16000 | 11000 | 3400 | 400 | 36 | 37 | 31 | 20 | 28 | 11 | 23 | 30 | 6.7 | 15 | 0.5 <W | 0.5 <W | 0.6 <T |
| S Maple St. | side | 3700 | 15000 | 9800 | 3100 | 360 | 31 | 30 | 27 | 19 | 25 | 12 | 19 | 25 | 5.7 | 15 | 0.5 <W | 0.5 <W | 0.4 <T |
| S Maple St. | back | 4200 | 16000 | 8400 | 3300 | 510 | 26 | 26 | 25 | 19 | 23 | 6.0 <T | 15 | 22 | 5.9 | 9.0 | 0.5 <W | 0.5 <W | 0.3 <T |
| S Maple St. | back | 4000 | 14000 | 8200 | 3100 | 450 | 25 | 21 <T | 24 | 19 | 23 | 10 | 13 | 20 | 5.3 | 6.8 | 0.5 <W | 0.5 <W | 0.3 <T |
| T Maple St. | front | 5100 | 23000 | 26000 | 4400 | 510 | 150 | 100 | 45 | 27 | 66 | 7.0 <T | 85 | 69 | 10 | 3.8 | 0.9 <T | 0.9 <T | 0.6 <T |
| T Maple St. | front | 5700 | 24000 | 29000 | 4500 | 570 | 170 | 110 | 48 | 30 | 60 | 5.0 <T | 94 | 74 | 11 | 5.5 | 1.1 <T | 0.5 <W | 0.8 <T |
| T Maple St. | side | 5200 | 23000 | 26000 | 4000 | 630 | 160 | 100 | 44 | 27 | 55 | 8.0 <T | 83 | 67 | 12 | 6.4 | 1.0 <T | 0.5 <W | 0.8 <T |
| T Maple St. | side | 5400 | 23000 | 30000 | 4200 | 540 | 180 | 110 | 48 | 30 | 62 | 7.0 <T | 94 | 76 | 11 | 4.8 | 1.1 <T | 0.5 <W | 0.8 <T |
| T Maple St. | back | 5000 | 19000 | 20000 | 4100 | 570 | 110 | 77 | 39 | 25 | 50 | 6.0 <T | 63 | 52 | 10 | 7.6 | 0.7 <T | 0.5 <W | 0.5 <T |
| T Maple St. | back | 4900 | 22000 | 26000 | 4200 | 550 | 150 | 100 | 46 | 28 | 56 | 6.0 <T | 88 | 68 | 11 | 4.0 | 1.0 <T | 0.7 <T | 0.7 <T |
| U Birch St. | front | 4600 | 18000 | 8300 | 4100 | 570 | 22 | 32 | 28 | 16 | 26 | 5.0 <T | 18 | 22 | 6.3 | 9.9 | 0.5 <W | 0.5 <W | 0.4 <T |
| U Birch St. | front | 3700 | 18000 | 8200 | 3500 | 560 | 22 | 37 | 26 | 16 | 28 | 9.0 <T | 18 | 22 | 6.4 | 14 | 0.5 <W | 0.5 <W | 0.7 <T |
| U Birch St. | back | 3000 | 16000 | 9900 | 3200 | 380 | 21 | 27 | 30 | 15 | 28 | 6.0 <T | 14 | 24 | 5.9 | 15 | 0.5 <W | 1.0 <T | 0.4 <T |
| U Birch St. | back | 3400 | 16000 | 9400 | 3300 | 530 | 33 | 44 | 29 | 18 | 25 | 9.0 <T | 16 | 17 | 7.1 | 12 | 0.5 <W | 0.5 <W | 0.6 <T |
| V Superior Ave. | front | 6800 | 23000 | 11000 | 5000 | 880 | 50 | 58 | 25 | 26 | 32 | 15 | 43 | 20 | 7.0 | 19 | 0.5 <W | 0.7 <T | 0.8 <T |
| V Superior Ave. | front | 7400 | 26000 | 12000 | 6200 | 910 | 53 | 58 | 32 | 25 | 45 | 15 <T | 49 | 29 | 8.5 | 20 | 0.5 <W | 0.5 <W | 0.6 <T |
| V Superior Ave. | back | 7600 | 23000 | 15000 | 5800 | 870 | 66 | 46 | 30 | 26 | 40 | 14 | 76 | 23 | 7.8 | 23 | 0.5 <W | 0.6 <T | 0.8 <T |
| V Superior Ave. | back | 7800 | 24000 | 14000 | 5700 | 970 | 67 | 51 | 28 | 26 | 40 | 13 | 56 | 24 | 7.0 | 22 | 0.5 <W | 0.5 <W | 0.6 <T |
| W Superior Ave. | front | 3600 | 18000 | 9300 | 4100 | 500 | 29 | 33 | 32 | 21 | 29 | 12 | 16 | 18 | 7.8 | 15 | 0.5 <W | 0.5 <W | 0.3 <T |
| W Superior Ave. | front | 3900 | 20000 | 9500 | 4300 | 530 | 25 | 34 | 34 | 18 | 33 | 17 | 17 | 19 | 7.2 | 16 | 0.5 <W | 0.5 <W | 0.3 <T |
| W Superior Ave. | back | 4400 | 20000 | 9800 | 3300 | 670 | 54 | 75 | 37 | 20 | 30 | 19 | 15 | 15 | 6.0 | 20 | 0.5 <W | 0.5 <W | 0.4 <T |
| W Superior Ave. | back | 3600 | 21000 | 10000 | 3400 | 630 | 46 | 67 | 37 | 17 | 30 | 20 | 12 | 14 | 5.7 | 20 | 0.5 <W | 0.5 <W | 0.7 <T |
| MOE Background Guideline | | 58000 | 33000 | 27000 | 16000 | 1300 | 210 | 160 | 91 | 78 | 71 | 120 | 85 | 43 | 21 | 17 | 1.2 | 2.5 | 1.0 |
| MOE Effects Guideline | | NG | NG | NG | NG | NG | 750 | 600 | 200 | NG | 750 | 200 | 225 | 200 | 40 | 20 | 1.2 | 40 | 12 |

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Table 3: Soil Element Concentrations (µg/g) on Residential Yards, Wawa Township Properties West of Third Ave. & Mission Rd.

| Address | Yard | Ca | Fe | Al | Mg | Mn | Ba | Zn | V | Sr | Cr | Pb | Cu | Ni | Co | As | Be | Mo | Cd | |
|--------------------------|-------|-------|-------|-------|-------|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| X Superior Ave. | front | 4700 | 24000 | 16000 | 5000 | 690 | 38 | 55 | 42 | 19 | 44 | 14 | 49 | 25 | 11 | 15 | 0.5 | <W | 2.6 | 0.6 |
| X Superior Ave. | front | 3700 | 20000 | 13000 | 4200 | 500 | 31 | 46 | 36 | 16 | 38 | 11 | 36 | 23 | 9.1 | 18 | 0.5 | <W | 1.6 | 0.4 |
| X Superior Ave. | back | 2900 | 21000 | 14000 | 3900 | 540 | 36 | 41 | 36 | 15 | 33 | 13 | 24 | 20 | 7.8 | 17 | 0.5 | <W | 0.9 | 0.7 |
| X Superior Ave. | back | 3400 | 22000 | 13000 | 4600 | 590 | 39 | 48 | 36 | 17 | 38 | 18 | 29 | 23 | 8.3 | 18 | 0.5 | <W | 1.2 | 0.5 |
| Y Regina Cres. | front | 3200 | 13000 | 8400 | 2600 | 490 | 28 | 30 | 24 | 15 | 20 | 11 | 8.0 | 12 | 5.1 | 14 | 0.5 | <W | 0.5 | 0.6 |
| Y Regina Cres. | front | 2900 | 13000 | 7800 | 2500 | 490 | 29 | 32 | 22 | 14 | 20 | 10 | 8.0 | 12 | 4.1 | 13 | 0.5 | <W | 0.5 | 0.6 |
| Y Regina Cres. | back | 2300 | 14000 | 7300 | 1700 | 570 | 41 | 36 | 21 | 13 | 19 | 21 | 8.0 | 7.6 | 3.2 | 28 | 0.5 | <W | 0.5 | 0.6 |
| Y Regina Cres. | back | 3200 | 20000 | 8800 | 2700 | 930 | 54 | 49 | 26 | 16 | 21 | 33 | 10 | 12 | 3.7 | 39 | 0.5 | <W | 0.5 | 0.7 |
| Z Regina Cres. | front | 5000 | 20000 | 14000 | 5000 | 510 | 41 | 53 | 37 | 22 | 38 | 15 | 43 | 25 | 11 | 9.9 | 0.5 | <W | 1.2 | 0.5 |
| Z Regina Cres. | front | 5000 | 20000 | 14000 | 4900 | 500 | 40 | 53 | 36 | 22 | 38 | 19 | 44 | 24 | 10 | 11 | 0.5 | <W | 1.4 | 0.5 |
| Z Regina Cres. | back | 5200 | 23000 | 12000 | 4600 | 780 | 53 | 71 | 38 | 25 | 30 | 14 | 17 | 20 | 7.6 | 17 | 0.5 | <W | 0.5 | 0.7 |
| Z Regina Cres. | back | 14000 | 22000 | 12000 | 4500 | 1700 | 210 | 110 | 34 | 120 | 30 | 23 | 24 | 20 | 8.3 | 20 | 0.5 | <W | 0.5 | 1.3 |
| AA Churchill Ave. | front | 3800 | 14000 | 8300 | 3100 | 360 | 25 | 30 | 24 | 17 | 23 | 9.0 | 9.0 | 14 | 4.6 | 11 | 0.5 | <W | 0.5 | 0.2 |
| AA Churchill Ave. | front | 3300 | 12000 | 7700 | 2800 | 320 | 23 | 28 | 22 | 14 | 21 | 16 | 8.0 | 13 | 4.7 | 11 | 0.5 | <W | 0.5 | 0.7 |
| AA Churchill Ave. | back | 2700 | 11000 | 7100 | 2500 | 270 | 21 | 28 | 22 | 13 | 19 | 9.0 | 7.0 | 12 | 4.7 | 8.4 | 0.5 | <W | 0.5 | 0.3 |
| AA Churchill Ave. | back | 3000 | 12000 | 7900 | 2800 | 360 | 24 | 30 | 24 | 15 | 21 | 10 | 8.0 | 13 | 4.0 | 15 | 0.5 | <W | 0.5 | 0.2 |
| AB Churchill Ave. | front | 3900 | 20000 | 11000 | 3200 | 990 | 67 | 120 | 35 | 21 | 26 | 47 | 19 | 15 | 6.0 | 20 | 0.5 | <W | 0.5 | 0.9 |
| AB Churchill Ave. | front | 4200 | 20000 | 11000 | 3200 | 1100 | 67 | 110 | 38 | 21 | 26 | 38 | 17 | 14 | 6.1 | 22 | 0.5 | <W | 0.5 | 0.7 |
| AB Churchill Ave. | back | 3500 | 18000 | 10000 | 3400 | 500 | 25 | 78 | 32 | 17 | 25 | 23 | 14 | 16 | 6.3 | 17 | 0.5 | <W | 0.5 | 0.6 |
| AB Churchill Ave. | back | 3300 | 16000 | 10000 | 3400 | 610 | 35 | 76 | 30 | 16 | 26 | 15 | 13 | 17 | 6.6 | 23 | 0.5 | <W | 0.5 | 0.4 |
| AC Magpie Rd. | front | 4200 | 14000 | 8100 | 3300 | 440 | 31 | 35 | 25 | 20 | 27 | 16 | 17 | 15 | 5.0 | 27 | 0.5 | <W | 0.5 | 0.4 |
| AC Magpie Rd. | front | 4600 | 16000 | 8300 | 3400 | 530 | 33 | 34 | 26 | 22 | 26 | 12 | 18 | 15 | 5.5 | 15 | 0.5 | <W | 0.5 | 0.4 |
| AC Magpie Rd. | back | 3500 | 21000 | 12000 | 3400 | 590 | 45 | 46 | 35 | 19 | 25 | 17 | 18 | 17 | 6.0 | 25 | 0.5 | <W | 0.5 | 0.5 |
| AC Magpie Rd. | back | 3300 | 22000 | 11000 | 3400 | 650 | 48 | 44 | 37 | 20 | 25 | 24 | 16 | 16 | 5.6 | 25 | 0.5 | <W | 0.5 | 0.6 |
| AD Third Ave. | front | 5300 | 23000 | 11000 | 4600 | 760 | 43 | 73 | 33 | 22 | 32 | 47 | 20 | 19 | 6.8 | 18 | 0.5 | <W | 0.5 | 0.5 |
| AD Third Ave. | front | 4700 | 23000 | 9700 | 4600 | 760 | 38 | 68 | 31 | 21 | 31 | 40 | 20 | 19 | 7.2 | 18 | 0.5 | <W | 0.6 | 0.7 |
| AD Third Ave. | back | 4100 | 21000 | 11000 | 4800 | 620 | 35 | 51 | 37 | 23 | 36 | 20 | 31 | 23 | 7.9 | 18 | 0.5 | <W | 0.5 | 0.4 |
| AD Third Ave. | back | 4300 | 22000 | 11000 | 5000 | 680 | 40 | 65 | 35 | 19 | 32 | 25 | 20 | 23 | 8.1 | 19 | 0.5 | <W | 0.5 | 0.6 |
| AE George St. | front | 3700 | 14000 | 9100 | 2600 | 400 | 46 | 40 | 26 | 20 | 24 | 22 | 14 | 13 | 4.6 | 21 | 0.5 | <W | 0.6 | 0.6 |
| AE George St. | front | 3300 | 14000 | 9800 | 2500 | 430 | 37 | 40 | 25 | 17 | 24 | 17 | 13 | 13 | 4.7 | 16 | 0.5 | <W | 0.5 | 0.4 |
| AE George St. | back | 2500 | 14000 | 8200 | 2600 | 380 | 24 | 39 | 25 | 15 | 23 | 20 | 10 | 13 | 3.9 | 21 | 0.5 | <W | 0.5 | 0.5 |
| AE George St. | back | 2900 | 14000 | 9000 | 3000 | 370 | 24 | 38 | 27 | 16 | 24 | 21 | 11 | 14 | 4.2 | 19 | 0.5 | <W | 0.5 | 0.5 |
| MOE Background Guideline | | 58000 | 33000 | 27000 | 16000 | 1300 | 210 | 160 | 91 | 78 | 71 | 120 | 85 | 43 | 21 | 17 | 1.2 | 2.5 | 1.0 | |
| MOE Effects Guideline | | NG | NG | NG | NG | NG | 750 | 600 | 200 | NG | 750 | 200 | 225 | 200 | 40 | 20 | 1.2 | 40 | | 12 |

Background guidelines are Table F and Effects guidelines are Table A in the MOE Guideline for Use at Contaminated Sites (1997). QTR98 used where no Table F is available, see Appendix NG - no Table A Effects guideline available

Table 3: Soil Element Concentrations (ug/g) on Residential Yards, Wawa Townsite Properties West of Third Ave. & Mission Rd.

| Address | Yard | Ca | Fe | Al | Mg | Mn | Ba | Zn | V | Sr | Cr | Pb | Cu | Ni | Co | As | Be | Mo | Cd | |
|--------------------------|-------|-------|-------|-------|-------|------|-----|------|-----|----|-----|-------|-----|-----|-----|-----|-----|-----|-----|----|
| AF Ross St. | side | 3200 | 16000 | 8900 | 2800 | 420 | 27 | 37 | 29 | 15 | 22 | 17 | 12 | 12 | 4.8 | 15 | 0.5 | <W | 0.5 | <T |
| AF Ross St. | side | 2600 | 14000 | 7800 | 2100 | 380 | 28 | 31 | 26 | 13 | 18 | 17 | 8.0 | 9.0 | 3.7 | 14 | 0.5 | <W | 0.5 | <T |
| AF Ross St. | front | 3700 | 15000 | 7500 | 3000 | 430 | 26 | 42 | 26 | 14 | 27 | 21 | 11 | 12 | 4.2 | 18 | 0.5 | <W | 0.5 | <T |
| AF Ross St. | front | 3900 | 15000 | 7600 | 3000 | 420 | 29 | 39 | 26 | 15 | 26 | 18 | 12 | 13 | 4.4 | 13 | 0.5 | <W | 0.5 | <W |
| AF Ross St. | back | 4800 | 16000 | 9200 | 3200 | 510 | 36 | 59 | 28 | 14 | 21 | 22 | 12 | 13 | 4.7 | 16 | 0.5 | <W | 0.5 | <T |
| AF Ross St. | back | 4200 | 15000 | 8600 | 2900 | 450 | 33 | 54 | 26 | 15 | 20 | 21 | 11 | 12 | 5.2 | 20 | 0.5 | <W | 0.5 | <T |
| AG Birch St. | front | 2900 | 15000 | 7900 | 2100 | 460 | 24 | 25 | 23 | 13 | 17 | 12 | 7.0 | 9.4 | 3.5 | 26 | 0.5 | <W | 0.5 | <W |
| AG Birch St. | front | 2700 | 15000 | 8300 | 1900 | 420 | 23 | 23<T | 24 | 12 | 17 | 12 | 6.0 | 9 | 3.1 | 28 | 0.5 | <W | 0.5 | <T |
| AG Birch St. | back | 3800 | 14000 | 8000 | 2200 | 500 | 41 | 51 | 23 | 21 | 19 | 19 | 13 | 12 | 3.5 | 17 | 0.5 | <W | 0.5 | <T |
| AG Birch St. | back | 2600 | 14000 | 7700 | 2100 | 400 | 25 | 35 | 23 | 14 | 19 | 15 | 8.0 | 11 | 3.9 | 19 | 0.5 | <W | 0.5 | <T |
| AH Churchill Ave. | front | 3200 | 15000 | 9400 | 2400 | 420 | 20 | 63 | 26 | 13 | 24 | 21 | 11 | 11 | 3.7 | 25 | 0.5 | <W | 0.5 | <W |
| AH Churchill Ave. | front | 3000 | 14000 | 9100 | 2300 | 380 | 19 | 43 | 24 | 11 | 24 | 24 | 10 | 10 | 3.5 | 22 | 0.5 | <W | 0.5 | <W |
| AH Churchill Ave. | back | 3300 | 20000 | 10000 | 3200 | 680 | 38 | 42 | 40 | 15 | 31 | 16 | 13 | 16 | 5.8 | 34 | 0.5 | <W | 0.5 | <T |
| AH Churchill Ave. | back | 3500 | 19000 | 9600 | 3100 | 660 | 39 | 51 | 38 | 14 | 29 | 20 | 12 | 14 | 5.3 | 28 | 0.5 | <W | 0.6 | <T |
| AI Poplar St. | front | 3300 | 15000 | 7800 | 3100 | 380 | 22 | 23<T | 29 | 18 | 27 | 10 | 12 | 13 | 4.9 | 11 | 0.5 | <W | 1.0 | <T |
| AI Poplar St. | front | 3800 | 17000 | 8800 | 3200 | 420 | 25 | 29 | 33 | 21 | 28 | 9.0<T | 14 | 15 | 5.6 | 13 | 0.5 | <W | 0.6 | <T |
| AI Poplar St. | back | 2700 | 19000 | 7600 | 3100 | 520 | 26 | 36 | 35 | 17 | 27 | 10 | 15 | 16 | 5.4 | 17 | 0.5 | <W | 0.5 | <W |
| AI Poplar St. | back | 2700 | 17000 | 6800 | 2900 | 460 | 25 | 36 | 30 | 17 | 22 | 7.0<T | 13 | 13 | 5.3 | 14 | 0.5 | <W | 0.7 | <T |
| AJ Tamarack Ave. | front | 3400 | 12000 | 6500 | 3000 | 320 | 20 | 31 | 22 | 14 | 25 | 8.0<T | 13 | 20 | 4.9 | 4.6 | 0.5 | <W | 0.5 | <W |
| AJ Tamarack Ave. | front | 3600 | 13000 | 6600 | 3000 | 340 | 22 | 35 | 22 | 16 | 27 | 8.0<T | 14 | 21 | 4.8 | 5.0 | 0.5 | <W | 0.5 | <T |
| AJ Tamarack Ave. | back | 4000 | 19000 | 22000 | 3700 | 450 | 130 | 85 | 39 | 24 | 49 | 4.0<T | 68 | 61 | 8.7 | 4.1 | 0.8 | <T | 0.5 | <T |
| AJ Tamarack Ave. | back | 3400 | 16000 | 18000 | 3300 | 380 | 100 | 67 | 34 | 20 | 42 | 4.0<T | 55 | 50 | 7.1 | 4.9 | 0.6 | <T | 0.5 | <T |
| AK Tamarack Ave. | front | 3600 | 13000 | 6900 | 2900 | 370 | 23 | 31 | 24 | 17 | 21 | 7.0<T | 16 | 21 | 4.9 | 4.3 | 0.5 | <W | 0.5 | <T |
| AK Tamarack Ave. | front | 3800 | 14000 | 6900 | 3000 | 440 | 25 | 30 | 23 | 18 | 22 | 6.0<T | 15 | 20 | 5.3 | 7.4 | 0.5 | <W | 0.5 | <W |
| AK Tamarack Ave. | back | 4100 | 18000 | 16000 | 3600 | 460 | 93 | 75 | 33 | 22 | 41 | 7.0<T | 56 | 49 | 7.6 | 4.5 | 0.6 | <T | 0.5 | <W |
| AK Tamarack Ave. | back | 3700 | 15000 | 13000 | 3200 | 380 | 71 | 66 | 29 | 20 | 34 | 5.0<T | 41 | 39 | 6.7 | 3.6 | 0.5 | <W | 0.5 | <W |
| AL Superior Ave. | front | 2400 | 12000 | 8000 | 3000 | 280 | 24 | 60 | 27 | 15 | 23 | 6.0<T | 12 | 15 | 5.7 | 11 | 0.5 | <W | 0.5 | <W |
| AL Superior Ave. | front | 3300 | 12000 | 8100 | 3200 | 320 | 35 | 29 | 26 | 19 | 24 | 4.0<T | 12 | 16 | 6.0 | 6.2 | 0.5 | <W | 0.5 | <W |
| AM George St. | front | 5000 | 12000 | 7000 | 3000 | 350 | 43 | 66 | 22 | 22 | 27 | 23 | 20 | 16 | 5.2 | 13 | 0.5 | <W | 0.5 | <T |
| AM George St. | front | 5100 | 12000 | 6600 | 2900 | 360 | 43 | 44 | 22 | 21 | 25 | 33 | 20 | 15 | 4.9 | 14 | 0.5 | <W | 0.5 | <W |
| AM George St. | back | 2900 | 13000 | 7500 | 2300 | 340 | 29 | 44 | 26 | 13 | 27 | 22 | 10 | 11 | 4.7 | 17 | 0.5 | <W | 0.5 | <T |
| AM George St. | back | 3800 | 14000 | 7700 | 2800 | 360 | 30 | 85 | 27 | 15 | 27 | 25 | 11 | 11 | 4.2 | 16 | 0.5 | <W | 0.5 | <W |
| MOE Background Guideline | | 58000 | 33000 | 27000 | 16000 | 1300 | 210 | 160 | 91 | 78 | 71 | 120 | 85 | 43 | 21 | 17 | 1.2 | 2.5 | 1.0 | |
| MOE Effects Guideline | | NG | NG | NG | NG | NG | 750 | 600 | 200 | NG | 750 | 200 | 225 | 200 | 40 | 20 | 1.2 | 40 | 12 | |

Background guidelines are Table F and Effects guidelines are Table A in the MOE Guideline for Use at Contaminated Sites (1997), OTR98 used where no Table F is available, see Appendix.
NG - no Table A Effects guideline available

Table 4: Correlation Coefficients (r) Between Pairs of Soil Chemical Elements

| | Ca | Fe | Al | Mg | Mn | Ba | Zn | V | Sr | Cr | Pb | Cu | Ni | Co | As | Be | Mo | Cd |
|----|--------|--------|---------|--------|---------|---------|---------|--------|--------|--------|---------|--------|--------|--------|---------|---------|--------|----|
| Ca | 1 | | | | | | | | | | | | | | | | | |
| Fe | 0.4559 | 1 | | | | | | | | | | | | | | | | |
| Al | 0.3475 | 0.3482 | 1 | | | | | | | | | | | | | | | |
| Mg | 0.6559 | 0.7751 | 0.4512 | 1 | | | | | | | | | | | | | | |
| Mn | 0.5336 | 0.9270 | 0.1660 | 0.6689 | 1 | | | | | | | | | | | | | |
| Ba | 0.5748 | 0.3014 | 0.8131 | 0.3234 | 0.2798 | 1 | | | | | | | | | | | | |
| Zn | 0.5022 | 0.6279 | 0.4203 | 0.5027 | 0.5995 | 0.4977 | 1 | | | | | | | | | | | |
| V | 0.3784 | 0.5176 | 0.7753 | 0.6110 | 0.3301 | 0.5666 | 0.5093 | 1 | | | | | | | | | | |
| Sr | 0.7908 | 0.2413 | 0.3202 | 0.3623 | 0.3742 | 0.6683 | 0.3592 | 0.3300 | 1 | | | | | | | | | |
| Cr | 0.4922 | 0.4891 | 0.8814 | 0.6948 | 0.3025 | 0.6913 | 0.5306 | 0.8046 | 0.3367 | 1 | | | | | | | | |
| Pb | 0.2475 | 0.4042 | -0.0186 | 0.2379 | 0.3861 | 0.0666 | 0.6819 | 0.1870 | 0.1231 | 0.1190 | 1 | | | | | | | |
| Cu | 0.4756 | 0.4442 | 0.9027 | 0.5830 | 0.2774 | 0.7839 | 0.4399 | 0.6403 | 0.3370 | 0.8863 | 0.0627 | 1 | | | | | | |
| Ni | 0.3167 | 0.3509 | 0.9017 | 0.4506 | 0.1758 | 0.7842 | 0.3749 | 0.6068 | 0.2828 | 0.8415 | -0.0758 | 0.9054 | 1 | | | | | |
| Co | 0.5319 | 0.5723 | 0.7587 | 0.8162 | 0.4073 | 0.5631 | 0.5459 | 0.8245 | 0.3887 | 0.8876 | 0.1776 | 0.7681 | 0.7100 | 1 | | | | |
| As | 0.2360 | 0.6355 | -0.0167 | 0.3935 | 0.6577 | -0.0005 | 0.3899 | 0.1496 | 0.0668 | 0.1333 | 0.3085 | 0.0633 | 0.0111 | 0.1635 | 1 | | | |
| Be | 0.1481 | 0.1389 | 0.8222 | 0.1476 | -0.0089 | 0.7591 | 0.2207 | 0.4499 | 0.1894 | 0.6448 | -0.1680 | 0.7577 | 0.8549 | 0.4534 | -0.1024 | 1 | | |
| Mo | 0.0767 | 0.1399 | 0.2404 | 0.2773 | 0.0314 | 0.0026 | -0.0461 | 0.3410 | 0.0107 | 0.3020 | -0.0446 | 0.2221 | 0.0867 | 0.3995 | -0.0561 | -0.0080 | 1 | |
| Cd | 0.4524 | 0.5189 | 0.2736 | 0.3901 | 0.5237 | 0.3741 | 0.6173 | 0.3707 | 0.3713 | 0.3230 | 0.5726 | 0.2923 | 0.1637 | 0.3843 | 0.1963 | 0.1108 | 0.0774 | 1 |

Table 5: Element Concentrations (ug/g) - Soil Used in Bioassay (mean of 3 or 4 analytical replicates)

| | Ca | Fe | Al | Mg | Mn | Ba | Zn | V | Sr | Cr | Pb | Cu | Ni | Co | As | Be | Mo | Cd | Na | Cl |
|----------------------|-------|---------------|-------|--------------|--------------|-----|------------|-----|----|-----|-----|-----|-----|-----|------------|-----|-----|-----|-----|-----|
| Site 1 | 3900 | 22250 | 9150 | 4750 | 645 | 32 | 69 | 33 | 22 | 34 | 32 | 27 | 22 | 8.2 | 14 | 0.5 | 0.7 | 0.5 | 118 | 13 |
| Site 2 | 6675 | 110000 | 7450 | 9400 | 5475 | 49 | 62 | 36 | 18 | 22 | 33 | 14 | 23 | 6.2 | 348 | 0.5 | 0.5 | 1.3 | 70 | 7.5 |
| Site 3 | 3700 | 37000 | 20750 | 4150 | 1200 | 55 | 79 | 43 | 19 | 36 | 40 | 20 | 23 | 7.6 | 108 | 0.5 | 0.6 | 1.0 | 118 | 19 |
| Site 4 | 8100 | 143333 | 7867 | 12333 | 7967 | 28 | 120 | 31 | 16 | 31 | 60 | 49 | 27 | 8.9 | 390 | 0.5 | 0.5 | 2.1 | 100 | 4.8 |
| Site 5 | 3200 | 15333 | 9667 | 2467 | 393 | 38 | 37 | 28 | 16 | 24 | 11 | 13 | 14 | 5.1 | 15 | 0.5 | 0.5 | 0.6 | 77 | 2.7 |
| Site 6 | 22000 | 263333 | 6500 | 21000 | 15333 | 21 | 81 | 23 | 37 | 26 | 3.3 | 30 | 40 | 19 | 497 | 0.5 | 0.5 | 3.3 | 67 | 2.1 |
| Site 7 | 5267 | 17000 | 6733 | 4200 | 483 | 24 | 47 | 28 | 17 | 34 | 10 | 17 | 18 | 7.3 | 14 | 0.5 | 0.5 | 0.6 | 87 | 4.5 |
| Site 8 | 6600 | 163333 | 6700 | 14333 | 9400 | 60 | 203 | 29 | 17 | 43 | 103 | 40 | 32 | 11 | 533 | 0.5 | 0.5 | 2.5 | 117 | 8.8 |
| Site 9 | 3867 | 40333 | 11333 | 3767 | 1900 | 27 | 56 | 21 | 12 | 20 | 19 | 7.0 | 14 | 4.3 | 143 | 0.5 | 0.5 | 0.8 | 60 | 4.5 |
| Site 10 | 3200 | 27333 | 9467 | 3533 | 1133 | 39 | 51 | 28 | 17 | 26 | 36 | 22 | 21 | 6.7 | 60 | 0.5 | 0.5 | 0.5 | 73 | 6.1 |
| Table F Guideline | 58000 | 33000 | 27000 | 16000 | 1300 | 210 | 160 | 91 | 78 | 71 | 120 | 85 | 43 | 21 | 17 | 1.2 | 2.5 | 1.0 | 910 | 220 |
| Table A Guideline | NG | NG | NG | NG | NG | 750 | 600 | 200 | NG | 750 | 200 | 225 | 200 | 40 | 20 | 1.2 | 40 | 12 | NG | NG |

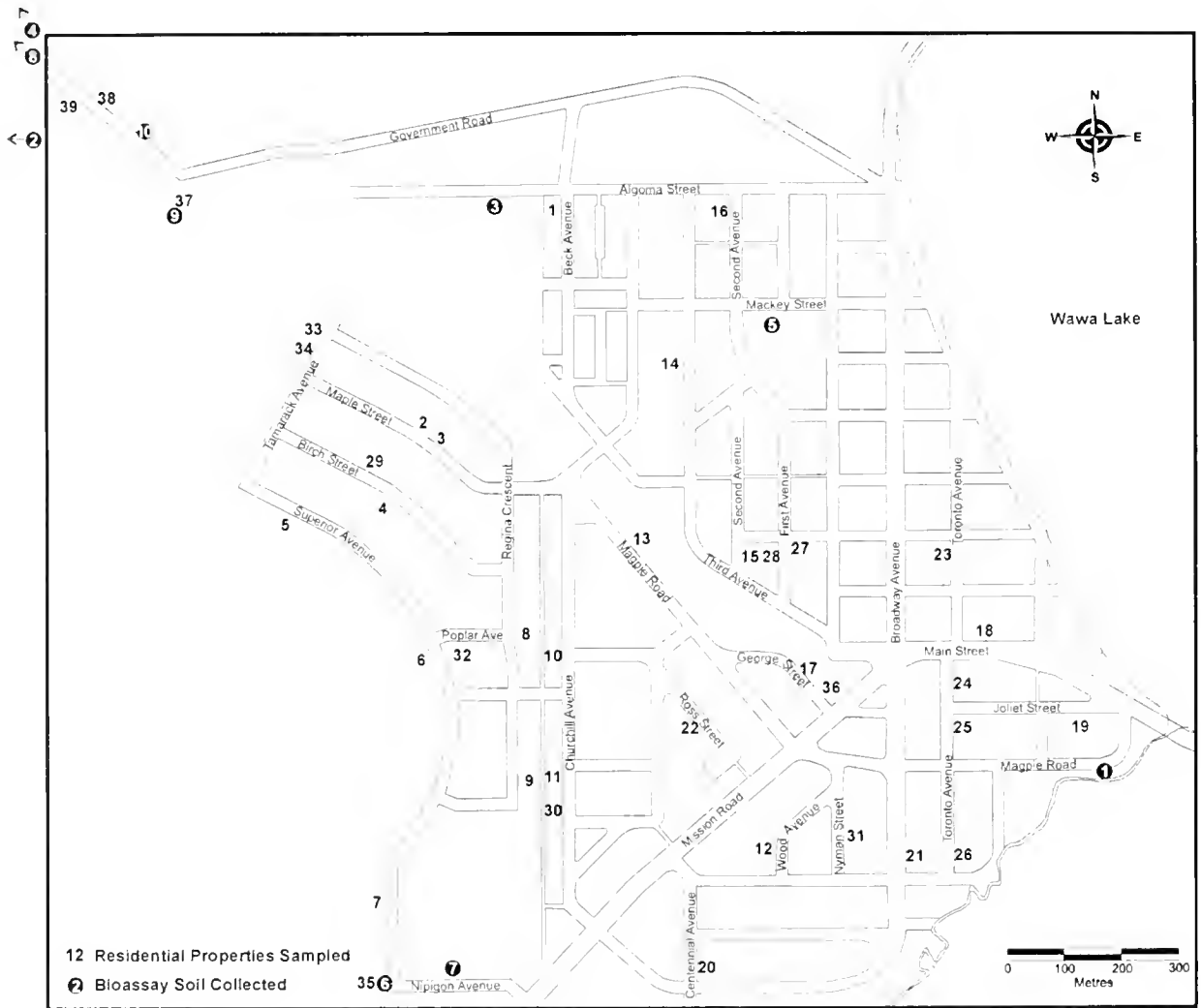
Background guidelines are Table F and Effects guidelines are Table A in the MOE Guideline for Use at Contaminated Sites (1997), OTR98 used where no Table F is available, see Appendix.

NG - no Table A Effects guideline available.

Table 6: Summary of Arsenic Bean Growth Bioassay Results

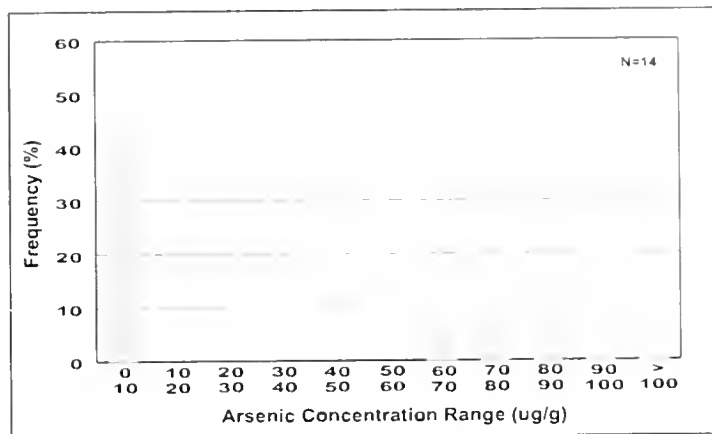
| Sample Site | Soil Arsenic in µg/g | Mean Shoot Fresh Weight in g (STD) | Mean Shoot Length in cm (STD) | Mean Root Length in cm (STD) |
|---|----------------------|------------------------------------|-------------------------------|------------------------------|
| Control | <17 | 1.71 (2.63) | 11.54 (3.56) | 17.08 (2.09) |
| 1 | 14 | 2.25 (3.48) | 14.27 (1.44) | 16.60 (4.24) |
| 7 | 14 | 2.67 (4.38) | 13.03 (1.99) | 19.52 (3.97) |
| 5 | 15 | 2.48 (3.82) | 12.60 (2.25) | 17.82 (3.06) |
| 10 | 60 | 1.99 (2.88) | 12.09 (2.41) | 18.76 (3.20) |
| 3 | 108 | 2.95 (4.61) | 13.51 (1.17) | 17.03 (2.82) |
| 9 | 143 | 2.26 (3.41) | 11.73 (2.16) | 18.78 (1.99) |
| 2 | 348 | 2.22 (3.63) | 13.30 (1.05) | 23.63 (5.31) |
| 4 | 390 | 2.46 (3.63) | 13.87 (2.15) | 20.03 (3.73) |
| 6 | 497 | 2.42 (3.14) | 12.47 (2.32) | 13.75 (2.72) |
| 8 | 533 | 1.77 (2.56) | 12.20 (1.03) | 18.75 (3.66) |
| Mean of 15 plants per treatment STD - Standard Deviation | | | | |

Figure 1: Location of Residential Properties Sampled and Bioassay Soil Collected

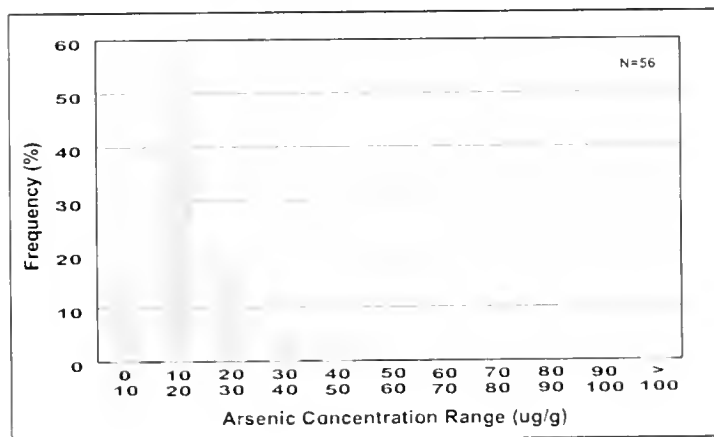


Phytotoxicity Study 2002
**Arsenic Concentrations - Frequency of Occurrence
 Residential Sites near Algoma Ore Division**

Figure 2:



**Arsenic Concentrations - Frequency of Occurrence
 Residential Sites Wawa East**



**Arsenic Concentrations - Frequency of Occurrence
 Residential Sites Wawa West**

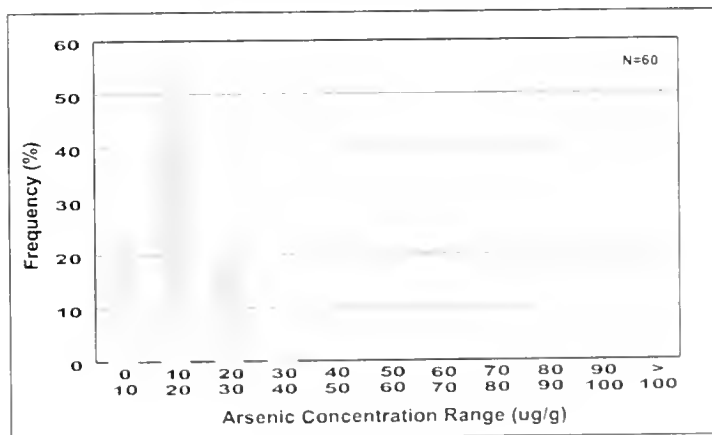
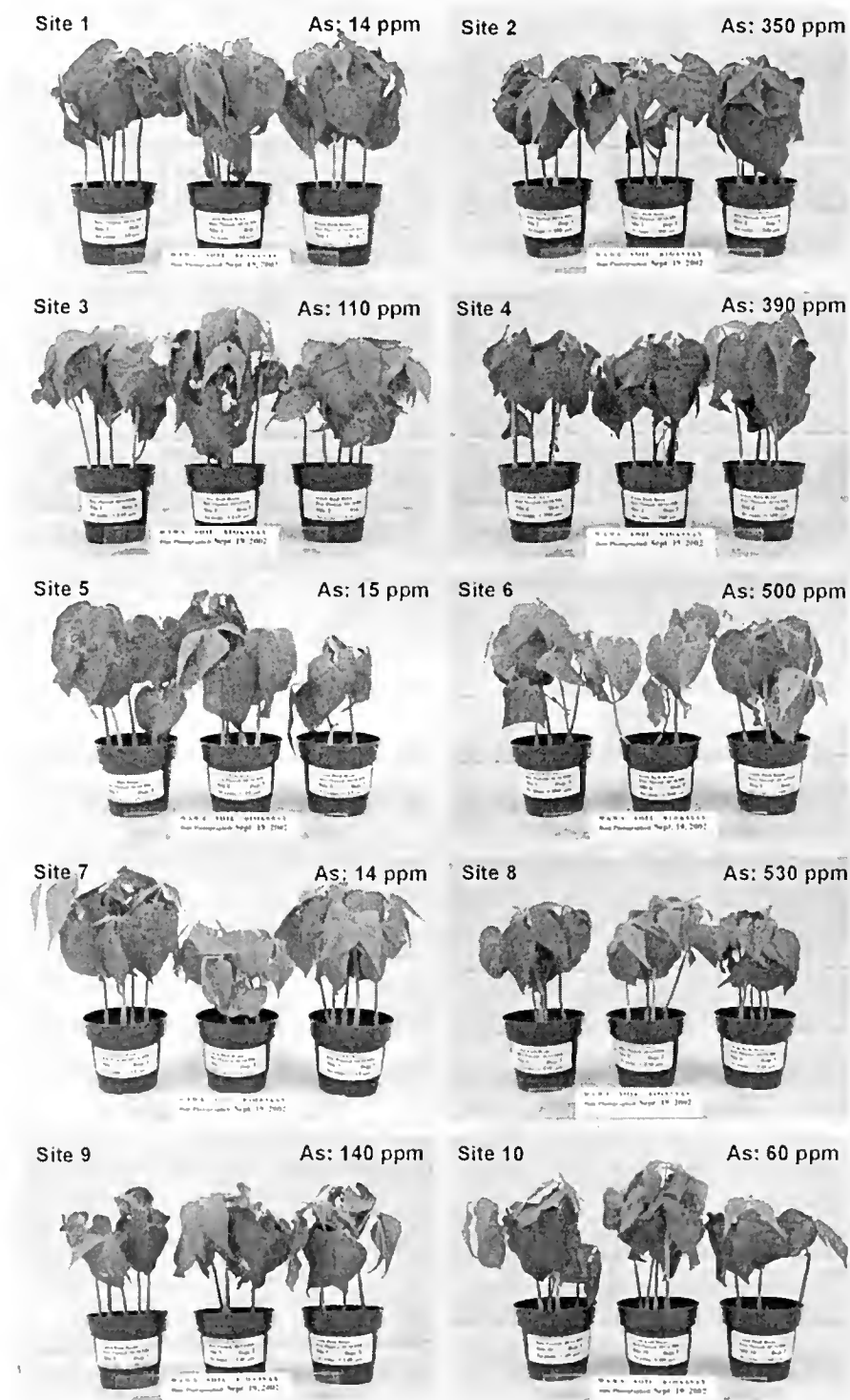


Figure 3: Bush Bean Plants Grown for 35 Days in 10 Soils from the Wawa Area



Appendix 1

Derivation/Significance of the Ontario Ministry of the Environment (MOE) Soil Guidelines in “*Guideline for Use at Contaminated Sites in Ontario*”

The MOE soil clean-up *Guidelines* have been developed to provide guidance for cleaning up contaminated soil. The *Guidelines* are not legislated Regulations. Also, the *Guidelines* are not action levels, in that an exceedence does not automatically mean that a clean-up must be conducted. The *Guidelines* were prepared to help industrial property owners decide how to clean-up contaminated soil when property is sold and/or the land-use changes. Most municipalities insist that contaminated soil is cleaned up according to the MOE *Guidelines* before they will approve a zoning change for redevelopment, therefore, even though the *Guideline* is voluntary most industrial property owners and developers are obliged to use it. For example, the owner of an industrial property who plans to sell the land to a developer who intends to build residential housing can use the *Guideline* to clean up the soil to meet the residential land-use criteria. In this way previously-contaminated industrial land can be re-used for residential housing without concern for adverse environmental effects.

The *Guideline* contains a series of Tables (A through F), each having criteria for soil texture, soil depth, and ground water use for various land-use categories (eg. agricultural, residential, industrial). Table F *criteria* reflect the upper range of background concentrations for soil in Ontario. An exceedence of Table F indicates the likely presence of a contaminant source. Tables A through E *criteria* are effects-based and are set to protect against the potential for adverse effects to human health, ecological health, and the natural environment, whichever is the most sensitive. By protecting the most sensitive parameter the rest of the environment is protected by default. The *Guideline criteria* take into consideration the potential for adverse effects through direct contact, and through contaminant transfer from soil to indoor air, from ground water or surface water through release of volatile gases, from leaching of contaminants in soil to ground water, or from ground water discharge to surface water. However, the *Guideline criteria may not* ensure that corrosive, explosive, or unstable soil conditions will be eliminated.

If the decision is made that remedial action is needed, the *criteria* in Tables A to F of the *Guideline* can be used as clean-up targets. In some cases, because of economic or practical reasons, it may not be possible to clean up a site using the generic *criteria* in Tables A to F. The *Guideline* provides a process, called a *site specific risk assessment*, which is used to evaluate the soil contamination with respect to conditions that are unique to the contaminated site. In a *site specific risk assessment* the proponent examines all the potential pathways through which the contamination may impact the environment and must demonstrate that because of conditions unique to that site the environment and human health will not be adversely effected if contamination above the generic *criteria* in Table A to E is left in place.

When contamination is present and a change in land-use is not planned, for example residential properties and public green spaces near a pollution source, the *Guideline* may be used in making decisions about the need for remediation. This is different from the previously described situation where a company that caused contamination on their own property decides to clean up the soil, usually at the insistence of the municipality who will not approve a zoning change unless remediation is conducted. Decisions on the need to undertake remedial action when the *Guideline criteria* are exceeded *and* where the land-use is not changing are made on a site by site basis using *site specific risk assessment* principals and are usually

contingent on the contaminants having caused an adverse environmental effect or there is a demonstrated likelihood that the contamination may cause an adverse effect. Because of the long history of industrial operation and our practice of living close to our work place the soil in many communities in Ontario is contaminated above the effects-based *criteria* in the MOE *Guidelines*. In practice, remediation of contaminated soil on privately-owned residential property and public green spaces has only been conducted in communities when the potential for adverse health effects has been demonstrated.

The soil clean-up *Guidelines* were developed from published U.S. EPA and Ontario environmental data bases. Currently there are criteria for about 25 inorganic elements and about 90 organic compounds. Criteria were developed only if there were sufficient, defensible, effects-based data on the potential to cause an adverse effect. All of the criteria address human health and aquatic toxicity, but terrestrial ecological toxicity information was not available for all elements or compounds. The development of these clean-up *Guidelines* is a continuous program, and criteria for more elements and compounds will be developed as additional environmental data become available. Similarly, new information could result in future modifications to the existing *Guidelines*.

For more information on the MOE's soil clean-up *Guidelines* please refer to the *Guideline for Use at Contaminated Sites in Ontario, Revised February 1997*, Ontario Ministry of Environment and Energy, PIBs 3161E01, ISBN 0-7778-6114-3.

Appendix 2

Derivation and Significance of the MOE "Ontario Typical Range" Soil Guidelines

The MOE "Ontario Typical Range" (OTR) guidelines are being developed to assist in interpreting analytical data and evaluating source-related impacts on the terrestrial environment. The OTRs are used to determine if the level of a chemical parameter in soil, plants, moss bags, or snow is significantly greater than the normal background range. An exceedence of the OTR_{98} (the OTR_{98} is the actual guideline number) may indicate the presence of a potential point source of contamination.

The OTR_{98} represents the expected range of concentrations of chemical parameters in surface soil, plants, moss bags, and snow from areas in Ontario not subjected to the influence of known point sources of pollution. The OTR_{98} represents 97.5 percent of the data in the OTR distribution. This is equivalent to the mean plus two standard deviations, which is similar to the previous MOE "Upper Limit of Normal" (ULN) guidelines. In other words, 98 out of every 100 background samples should be lower than the OTR_{98} .

The OTR_{98} may vary between land use categories even in the absence of a point source of pollution because of natural variation and the amount and type of human activity, both past and present. Therefore, OTRs are being developed for several land use categories. The three main land use categories are Rural, New Urban, and Old Urban. Urban is defined as an area that has municipal water and sewage services. Old Urban is any area that has been developed as an urban area for more than 40 years. Rural is all other areas. These major land use categories are further broken into three subcategories: Parkland (which includes greenbelts and woodlands), Residential, and Industrial (which includes heavy industry, commercial properties such as malls, and transportation rights-of-way). Rural also includes an Agricultural category.

The OTR guidelines apply only to samples collected using standard MOE sampling, sample preparation, and analytical protocols. Because the background data were collected in Ontario, the OTRs represent Ontario environmental conditions.

The OTRs are not the only means by which results are interpreted. Data interpretation should involve reviewing results from control samples, examining all the survey data for evidence of a pattern of contamination relative to the suspected source, and where available, comparison with effects-based guidelines. The OTRs are particularly useful where there is uncertainty regarding local background concentrations and/or insufficient samples were collected to determine a contamination gradient. OTRs are also used to determine where in the anticipated range a result falls. This can identify a potential concern even when a result falls within the guideline. For example, if all of the results from a survey are close to the OTR_{98} , this could indicate that the local environment has been contaminated above the anticipated average, and therefore the pollution source should be more closely monitored.

The OTRs identify a range of chemical parameters resulting from natural variation and normal human activity. As a result, it must be stressed that values falling within a specific OTR_{98} should not be considered as acceptable or desirable levels; nor does the OTR_{98} imply toxicity to plants, animals or humans. Rather, the OTR_{98} is a level which, if exceeded, prompts further investigation on a case by case basis to determine the significance, if any, of the above normal concentration. Incidental, isolated or spurious exceedences of an OTR_{98} do not necessarily indicate a need for regulatory or abatement activity. However, repeated and/or

extensive exceedences of an OTR₉₈ that appears to be related to a potential pollution source does indicate the need for a thorough evaluation of the regulatory or abatement program.

The OTR₉₈ supersedes the Phytotoxicology ULN guideline. The OTR program is on-going. The number of OTRs will be continuously updated as sampling is completed for the various land use categories and sample types. For more information on these guidelines please refer to Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags, and Snow, MOEE Report Number HCB-151-3512-93, PIBs Number 2792, ISBN 0-778-1979-1.

| Method | Description |
|--------|---|
| E3015A | THE DETERMINATION OF FREE AND TOTAL CYANIDE IN ENVIRONMENTAL SAMPLES BY COLOURIMETRY |
| E3016A | THE DETERMINATION OF CHLORIDE IN DRINKING WATER, SURFACE WATER, SEWAGE AND INDUSTRIAL WASTE BY COLOURIMETRY |
| E3051A | THE DETERMINATION OF TRACE METALS IN POTABLE WATERS BY INDUCTIVELY COUPLED PLASMA-MASS SPECTROMETRY (ICP-MS) |
| E3056A | THE DETERMINATION OF HEXAVALENT CHROMIUM IN WATER, LANDFILL LEACHATES AND EFFLUENTS BY COLOURIMETRY |
| E3060B | THE DETERMINATION OF MERCURY IN WATER BY COLD VAPOUR-FLAMELESS ATOMIC ABSORPTION SPECTROPHOTOMETRY (CV-FAAS) |
| E3100A | THE DETERMINATION OF TOTAL SULPHIDE IN WATER, SEWAGE AND INDUSTRIAL WASTES BY COLOURIMETRY |
| E3115A | THE ENUMERATION OF "SULPHATE REDUCING" BACTERIA IN WATER BY THE INDICATED NUMBER METHOD |
| E3119A | THE DETERMINATION OF CHLOROPHENOLS (CPS) AND PHENOXYACID HERBICIDES (PAS) IN WATER BY SOLID PHASE EXTRACTION (SPE) AND IN VEGETATION BY SOLID/LIQUID EXTRACTION (SONIFICATION) USING GAS CHROMATOGRAPHY-MASS SPECTROMETRY (GC-MS) |
| E3132A | THE DETERMINATION OF VOLATILE ORGANOHALIDES AND HYDROCARBONS IN WATER, LEACHATES AND EFFLUENTS BY HEADSPACE CAPILLARY GAS CHROMATOGRAPHY (GC) MASS SPECTROMETRY AND/OR PURGE AND TRAP GAS CHROMATOGRAPHY (GC) MASS SPECTROMETRY |
| E3144B | THE DETERMINATION OF VOLATILE ORGANIC COMPOUNDS IN RAW AND TREATED DRINKING WATER BY PURGE AND TRAP CAPILLARY GAS CHROMATOGRAPHY- FLAME IONIZATION/MASS SELECTIVE (PT/GC-FID/MSD) DETECTION |
| E3170A | THE DETERMINATION OF CHEMICAL OXYGEN DEMAND (COD) IN DOMESTIC AND SURFACE WATERS BY COLOURIMETRY |
| E3172A | THE DETERMINATION OF FLUORIDE AND SULPHATE IN WATER, LEACHATES AND EFFLUENTS BY AUTOMATED ION CHROMATOGRAPHY (IC) |
| E3179A | THE DETERMINATION OF PHENOLIC COMPOUNDS IN WATER, INDUSTRIAL WASTES, LANDFILL LEACHATES AND SEWAGE BY COLOURIMETRY |
| E3186A | THE CHARACTERIZATION OF EXTRACTABLE ORGANICS IN WATER, WASTE AND SOIL BY GAS CHROMATOGRAPHY-MASS SPECTROMETRY (GC-MS) |
| E3188B | THE DETERMINATION OF SOLIDS IN LIQUID MATRICES BY GRAVIMETRY |
| E3189A | THE CHARACTERIZATION OF VOLATILE ORGANICS IN WATER AND EFFLUENT BY PURGE-AND-TRAP GAS CHROMATOGRAPHY-MASS SPECTROMETRY (GC-MS) |
| E3196A | LIMS CALCULATIONS-ION BALANCE |

| Method | Description |
|--------|--|
| E3217A | THE DETERMINATION OF CATIONS IN WATER, SEWAGE, HEALTH SAMPLES, INDUSTRIAL WASTE AND LANDFILL LEACHATES BY ATOMIC ABSORPTION SPECTROPHOTOMETRY (AAS) |
| E3218A | THE DETERMINATION OF CONDUCTIVITY, pH AND ALKALINITY IN WATER AND EFFLUENTS BY POTENTIOMETRY |
| E3219A | THE DETERMINATION OF TRUE COLOUR IN WATER, EFFLUENTS AND INDUSTRIAL WASTES BY COLOURIMETRY |
| E3226A | THE DETECTION OF COLIFORM BACTERIA INCLUDING ESCHERICHIA COLI IN DRINKING WATER BY THE PRESENCE-ABSENCE PROCEDURE |
| E3247B | THE DETERMINATION OF TOTAL ORGANIC CARBON IN AQUEOUS SAMPLES BY COMBUSTION AND INFRARED SPECTROMETRY |
| E3274A | LIMS CALCULATIONS-LANGELIERS INDEX |
| E3291A | THE DETERMINATION OF N-NITROSODIMETHYLAMINE (NDMA) IN WATER BY GAS CHROMATOGRAPHY-HIGH RESOLUTION MASS SPECTROMETRY (GC-HRMS) |
| E3310A | THE DETERMINATION OF TASTE AND ODOUR COMPOUNDS IN WATER BY GAS CHROMATOGRAPHY-HIGH RESOLUTION MASS SPECTROMETRY (GC-HRMS) |
| E3311A | THE DETERMINATION OF TURBIDITY IN WATER BY NEPHELOMETRY UNDER ROBOTIC CONTROL |
| E3364A | THE DETERMINATION OF AMMONIA NITROGEN, NITRITE NITROGEN, NITRITE PLUS NITRATE NITROGEN AND REACTIVE ORTHO-PHOSPHATE IN SURFACE WATER, DRINKING WATER AND PRECIPITATION BY COLOURIMETRY |
| E3367A | THE DETERMINATION OF TOTAL KJELDAHL NITROGEN AND TOTAL PHOSPHOROUS IN WATER, PRECIPITATION AND SOIL EXTRACTS BY COLOURIMETRY |
| E3370A | THE DETERMINATION OF MOLYBDATE REACTIVE SILICATES AND DISSOLVED CARBON IN WATER, INDUSTRIAL WASTE, SOIL EXTRACTS AND PRECIPITATION BY COLOURIMETRY |
| E3371A | A MEMBRANE FILTRATION METHOD FOR THE DETECTION AND ENUMERATION OF TOTAL COLIFORM, ESCHERICHIA COLI, PSEUDOMONAS AERUGINOSA AND FECAL STREPTOCOCCI |
| E3388A | THE DETERMINATION OF N-NITROSAMINES IN WATER BY GAS CHROMATOGRAPHY - HIGH RESOLUTION MASS SPECTROMETRY (GC-HRMS) |
| E3399A | THE DETERMINATION OF POLYCYCLIC HYDROCARBONS (PAH) IN AQUEOUS MATRICES BY LIQUID-LIQUID MICRO-EXTRACTION (LLME) AND GAS CHROMATOGRAPHY - MASS SPECTROMETRY (GC-MS) |
| E3400A | THE DETERMINATION OF ORGANOCHLORINE PESTICIDES, CHLOROBENZENES (CBS), AROCLORS AND TOXAPHENES IN WATER, EFFLUENT AND WASTEWATER BY HEXANE MICROEXTRACTION AND GAS CHROMATOGRAPHY - MASS SPECTROMETRY (GC-MS) |
| E3406A | THE DETERMINATION OF NITRILOTRIACETIC ACID (NTA) IN AQUEOUS SAMPLES BY AUTOMATED ION CHROMATOGRAPHY (IC) |

| Method | Description |
|--------|--|
| E3407A | MEMBRANE FILTRATION METHOD USING DC AGAR FOR THE SIMULTANEOUS DETECTION AND ENUMERATION OF TOTAL COLIFORMS AND ESCHERICHIA COLI |
| E3408A | THE SPREAD PLATE METHOD FOR THE ENUMERATION OF AEROBIC HETEROTROPHIC BACTERIA IN DRINKING WATER |
| E3415 | THE DETERMINATION OF GLYPHOSATE AND AMINOMETHYLPHOSPHONIC ACID IN WATER AND VEGETATION BY HIGH PERFORMANCE LIQUID CHROMATOGRAPHY -ELECTROSPRAY IONIZATION- MASS SPECTROMETRY (HPLC-ESI-MS) |
| E3417 | THE DETERMINATION OF DIQUAT AND PARAQUAT IN WATER, SOIL AND VEGETATION ENVIRONMENTAL MATRICES BY HIGH PERFORMANCE LIQUID CHROMATOGRAPHY (HPLC) PHOTDIODE ARRAY AND/OR ELECTRO-SPRAY MASS SPECTROMETRY (MS) |
| E3418 | THE DETERMINATION OF POLYCHLORINATED DIBENZO-P-DIOXINS, POLYCHLORDIBENZOFURANS AND DIOXIN-LIKE POLYCHLORINATED BIPHENYLS IN ENVIRONMENTAL SAMPLES BY GAS CHROMATOGRAPHY-MASS SPECTROMETRY (GC-MS) |
| E3430 | THE DETERMINATION OF BROMINATED DIPHENYL ETHERS IN ENVIRONMENTAL MATRICES BY GAS CHROMATOGRAPHY/HIGH RESOLUTION MASS SPECTROMETRY (GC-HRMS) |
| E3434 | THE DETERMINATION OF BROMIDE IN SOURCE WATER BY ION CHROMATOGRAPHY/ELECTROCHEMICAL DETECTION AND TRACE LEVELS OF BROMATE IN OZONATED DRINKING WATER WITH THE ADDITION OF POSTCOLUMN REAGENT AND A UV/VISIBLE DETECTOR |
| E3435 | THE DETERMINATION OF POLYCYCLIC AROMATIC HYDROCARBONS AND TRIAZINE PESTICIDES IN WATER MATRICES BY GAS CHROMATOGRAPHY-TIME OF FLIGHT-MASS SPECTROMETRY |
| E3436 | THE DETERMINATION OF PHENYL UREAS IN WATER AND LEACHATE BY HIGH PERFORMANCE LIQUID CHROMATOGRAPHY AND MASS SPECTROMETRY-MASS SPECTROMETRY (LC-MS-MS) ANALYSIS |
| E3437 | THE DETERMINATION OF ORGANOPHOSPHORUS PESTICIDES IN WATER AND LEACHATE BY HIGH PERFORMANCE LIQUID CHROMATOGRAPHY AND MASS SPECTROMETRY-MASS SPECTROMETRY (LC-MS-MS) ANALYSIS |
| E3438 | THE DETERMINATION OF CARBAMATES IN WATER AND LEACHATE BY HIGH PERFORMANCE LIQUID CHROMATOGRAPHY AND MASS SPECTROMETRY-MASS SPECTROMETRY (LC-MS-MS) ANALYSIS |
| E3449 | THE DETERMINATION OF MOSQUITO LARVACIDE AND ADULTICIDE AND THE SCREENING OF DECOMPOSITION BY-PRODUCTS OF METHOPRENE IN ENVIRONMENTAL MATRICES USING MICRO-EXTRACTION AND GAS CHROMATOGRAPHY-TIME OF FLIGHT-MASS SPECTROMETRY |
| E3450 | THE DETERMINATION OF MICROCYSTINS AND NODULARIN IN WATER BY LIQUID CHROMATOGRAPHY-(ELECTROSPRAY IONIZATION) TANDEM MASS SPECTROMETRY [LC-(ESI)MS/MS] |
| E3451 | THE DETECTION AND ENUMERATION OF BACILLUS THURINGIENSIS VAR. ISRAELENSIS (BTI) IN DRINKING WATER BY MEMBRANE FILTRATION AND THE COLONY PCR METHOD |
| E3454 | THE DETERMINATION OF PHARMACEUTICALS IN ENVIRONMENTAL MATRICES BY LIQUID CHROMATOGRAPHY/MASS SPECTROMETRY/MASS SPECTROMETRY |

